VOLUME LVII NUMBER 4

THE
BOTANICAL GAZETTE

APRIL 1914

THE EFFECT OF SHADING ON THE TRANSPIRATION AND ASSIMILATION OF THE TOBACCO PLANT IN CUBA

HEINRICH HASSELBRING

(WITH ONE FIGURE)

Introduction

This paper gives an account of experiments conducted in Western Cuba for the purpose of determining the effect on transpiration and assimilation in the tobacco plant of the cheese-cloth shade which is frequently used in that region for shading tobacco. A comparative study of the transpiration and assimilation of the tobacco plant under normal conditions and under the conditions induced by cheese-cloth shading is of interest for several reasons. First, although investigations[1] of the influence of different light intensities on transpiration have nearly always led to the conclusion that the rate of transpiration is decreased with a lessening illumination, the experiments which have established this conclusion have necessarily been conducted with plants or parts of plants which could be kept under observation only for short periods of time, and often under laboratory conditions. Data permitting a comparison of the transpiration of plants under normal conditions with others of the same kind shaded during their entire development are not at

[1] KOHL, G., Die Transpiration der Pflanzen, etc. pp. 52–74. 1886; BURGERSTEIN, A., Die Transpiration der Pflanzen. pp. 85–103. 1904; LIVINGSTON, B. E., Light intensity and transpiration. BOT. GAZ. **52**:417–438. 1911.

hand.[2] Second, in view of the fact that a large portion of the tobacco crop is grown regularly under shade, such data would not be devoid of practical interest, especially in regions like Western Cuba, where annual crops require irrigation and where much of the irrigation is accomplished by toilsome hand labor. Finally, in the minds of investigators, transpiration has frequently been associated with assimilation. The water requirement of agricultural crops has usually been stated in a ratio of the quantity of water transpired to dry substance produced. As a rule, this ratio has been considered merely as a convenient empirical expression of the water-utilization of plants; but some writers have assumed a closer relation and have postulated a direct influence of transpiration on production, or conversely. Therefore, it is of interest to determine to what extent the conditions induced by shade, either directly or through their influence on transpiration, affect production.

For these reasons, the work described in the following pages was undertaken at the Cuban Agricultural Experiment Station at Santiago de las Vegas during the season of 1908–1909. For constant and ready aid in carrying out the exacting work required for this investigation, I am much indebted to ENRIQUE IBAÑEZ and AUGUSTIN GARCIA, at that time my assistants at the station.

Environment

GENERAL STATEMENT

For the purpose of these experiments, six tobacco plants were grown in the open ground, and six under cheese-cloth shade in a manner described later. The cheese-cloth was of the kind generally used in Cuba and elsewhere for shading tobacco (fig. 1). During the middle of the day, when the sun's rays are nearly perpendicular, this cloth casts a barely perceptible shadow, which, however, is more noticeable early in the morning or late in the afternoon. In

[2] FITTBOGEN indeed grew to maturity some plants of oats in a greenhouse and others in the open. He regarded the loss of light due to its passage through the glass as one of the factors tending to lower the transpiration of the plants. This experiment, however, can hardly be classed as a study of the effect of shading on transpiration. FITTBOGEN, J., Über Wasserverdunstung der Haferpflanze unter verschiedenen Wärme-, Licht-, und Luftfeuchtigkeits-Verhältnissen. Landw. Jahrb. 3:141–146. 1874.

order to determine the effect of the cheese-cloth on the environment of the plants, measurements were made during the course of the experiments of the various environmental factors both under the

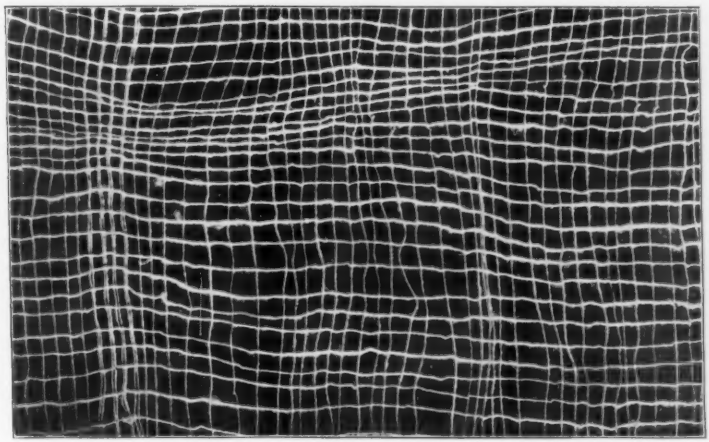

FIG. 1.—Photograph of the cheese-cloth used in the experiments; natural size

cheese-cloth and in the open. The results of these measurements are given in the following paragraphs.

LIGHT

The light intensity under the two conditions was measured by the photometric method. The method in general was that described by WIESNER[3] and used by him in his extensive researches on the light relations of plants. However, owing to the difficulty of making a sensitive paper which at some stage in the process of darkening would exactly match the normal tint kindly sent the writer by Professor WIESNER, a standard instrument, the Wynne exposure-meter, was used in these observations. The time of exposure was measured by means of a stop-watch. The applicability of this method, as well as its shortcomings, have been fully discussed by WIESNER and others, and recently LIVINGSTON[4] has subjected

[3] WIESNER, J., Der Lichtgenuss der Pflanzen. pp. 10–33. 1907.

[4] LIVINGSTON, *loc. cit.*

to a critical comparison this and other methods of measurement of solar energy. These discussions need not be repeated here. In spite of the shortcomings of this method, it has the advantage of being capable of easy manipulation and gives sufficiently correct results for a comparison of relative light values under the cheesecloth shade and in the open.

The observations were taken on December 12, December 23, and January 25. December 12 and January 25 were bright days with only a few hazy clouds, which are usual in Cuba toward the middle of the day. December 23 was cloudy, so that all the light on that day was diffuse. On the first day, December 12, ten observations were taken usually at each hour period for each kind of light under each condition, but on account of the length of time required to make that number of observations and the change of light meanwhile, only five observations were taken at each reading on the other days. As a rule, the observations were taken alternately within and without the tent. Since the personal equation in the judgment of color is likely to play an important part in determining the time required for the sensitive paper to reach a standard tint, the probable error of the average was calculated for each set of observations, except some taken early or late in the day, when, on account of the weakness of the light, it was not possible in some cases to take more than one or two observations. An examination of the probable errors given with the column of averages shows that it is not of undue magnitude. It may also be stated that the ten or five observations from which the average is made up showed a very close agreement, usually within a fraction of a second of each other except when the exposures were very long, that is, 30 seconds or more, although, as has been stated, the observations were taken alternately in the two stations in such a way that the observer was not influenced by the previous observation and record. From the observations thus made each hour in each station, the average time of exposure was calculated. These averages with their probable errors are given in table I.

The light intensity is of course proportional to the reciprocal of the time of exposure. These reciprocals were obtained, therefore, but in order to reduce the figures of each day to relative values, the

highest light intensity for each day was assigned the value of 10, and the other values were reduced to the same basis. These figures are given in table II. The relative light values for any one day, therefore, are all directly comparable, but the figures for one

TABLE I

AVERAGE LENGTHS (IN SECONDS) OF EXPOSURES MADE IN DETERMINING LIGHT VALUES

TIME OF EXPOSURE	OPEN		SHADE	
	Total light	Diffuse light	Total light	Diffuse light
December 12				
8:15– 8:30 A.M.	5.33±0.12	10.66±0.10	8.72±0.10	12.13±0.25
9:15– 9:30 A.M.	3.56±0.07	6.90±0.13	6.22±0.11	9.72±0.13
10:00–10:15 A.M.	2.92±0.09	7.58±0.18	4.36±0.10	7.31±0.11
11:00–11:15 A.M.	2.23±0.05	8.26±0.13	3.29±0.02	9.32±0.12
12:30– 1:00 P.M.	2.32±0.06	7.55±0.13	3.06±0.11	9.29±0.10
1:30– 2:00 P.M.	3.58±0.07	9.67±0.10	5.13±0.07	10.48±0.21
2:30– 3:00 P.M.	5.16±0.11	12.30±0.23	7.14±0.19	10.33±0.12
3:30– 4:00 P.M.	8.70±0.18	17.26±0.18	11.34±0.12	15.48±0.34
4:45– 5:15 P.M.	24.32±0.95	60.00	134.30	.....
December 23				
7:00 A.M.	.....	33.07±0.86	.....	56.33±1.03
8:00 A.M.	.....	10.68±0.89	.....	15.68±0.57
9:00 A.M.	.....	6.46±0.12	.....	9.23±0.49
10:00 A.M.	.....	7.72±0.18	.....	12.52±0.12
11:00 A.M.	.....	6.76±0.41	.....	8.80±0.50
12:00 M.	.....	10.68±0.17	.....	13.66±0.18
1:00 P.M.	.....	5.14±0.08	.....	7.84±0.08
2:00 P.M.	.....	6.34±0.16	.....	8.44±0.08
3:00 P.M.	.....	6.96±0.08	.....	10.56±0.11
4:00 P.M.	.....	14.36±0.28	.....	21.40±0.34
5:00 P.M.	.....	87.50±3.04	.....	94.00±0.67
January 25				
7:00 A.M.	59.50±2.36	.....	71.00±4.05	.....
8:00 A.M.	8.80±0.06	.....	13.65±0.10	.....
9:00 A.M.	3.60±0.07	8.48±0.08	7.12±0.12	11.20±0.10
10:00 A.M.	3.00±0.06	10.32±0.14	6.32±0.10	11.60±0.20
11:00 A.M.	2.34±0.09	6.88±0.16	4.76±0.11	7.82±0.07
12:00 M.	2.04±0.05	6.92±0.16	3.60±0.08	8.16±0.08
1:00 P.M.	2.48±0.05	7.68±0.09	4.00±0.06	8.56±0.16
2:00 P.M.	3.52±0.08	10.08±0.12	5.44±0.10	11.35±0.17
3:00 P.M.	5.60±0.21	13.12±0.29	8.12±0.09	14.68±0.22
4:00 P.M.	7.20±0.09	20.00±0.30	18.48±0.26	.....

day are not directly comparable with those of another day, since for each day a different number was taken as the unit. This system was adopted since it was not the purpose to compare the light values of the different days, but only those within the cheesecloth tent with those outside.

From table II the following conclusions may be drawn: On the bright days (December 12 and January 25) the total light within the tent was 30–40 per cent, or about one-third, less than that without, but the diffuse light showed very little difference in the two stations on those days. On December 23, however, when there was no bright sun, the total light in the tent (all diffuse) was reduced by about one-third. On the bright days the ratio of diffuse light to total light was much higher in the tent than in the open. The

TABLE II

RELATIVE LIGHT VALUES UNDER CHEESE-CLOTH SHADE AND IN THE OPEN

TIME OF OBSERVATION	TOTAL LIGHT		DIFFUSE LIGHT		RATIO $\frac{\text{DIFFUSE}}{\text{TOTAL}}$	
	Open	Shade	Open	Shade	Open	Shade
December 12						
8:15– 8:30 A.M.	4.2	2.5	2.1	1.8	0.50	0.72
9:15– 9:30 A.M.	6.3	3.6	3.2	2.3	0.51	0.64
10:00–10:15 A.M.	7.6	5.1	2.9	3.0	0.38	0.59
11:00–11:15 A.M.	10.0	6.8	2.7	2.4	0.27	0.35
12:30– 1:00 P.M.	9.6	7.3	2.9	2.4	0.30	0.33
1:30– 2:00 P.M.	6.2	4.3	2.3	2.1	0.37	0.49
2:30– 3:00 P.M.	4.3	3.1	1.8	2.2	0.42	0.71
3:30– 4:00 P.M.	2.5	2.0	1.3	1.4	0.52	0.70
4:45– 5:15 P.M.	0.9	0.2	0.4	.....	0.44	.....
December 23						
7:00 A.M.	.....	.....	1.6	0.9	.....	.....
8.00 A.M.	.....	.....	4.8	3.3	.....	.....
9:00 A.M.	.....	.....	7.9	5.6	.....	.....
10:00 A.M.	.....	.....	6.7	4.1	.....	.....
11:00 A.M.	.....	.....	7.6	5.8	.....	.....
12:00 M.	.....	.....	4.8	3.8	.....	.....
1:00 P.M.	.....	.....	10.0	6.5	.....	.....
2:00 P.M.	.....	.....	8.1	6.1	.....	.....
3:00 P.M.	.....	.....	7.4	4.9	.....	.....
4:00 P.M.	.....	.....	3.6	2.4	.....	.....
5:00 P.M.	.....	.....	0.6	0.5	.....	.....
January 25						
7:00 A.M.	0.3	0.3	.....	.....	.....	.....
8:00 A.M.	2.3	1.5	.....	.....	.....	.....
9:00 A.M.	5.7	2.9	2.4	1.8	0.42	0.62
10:00 A.M.	6.8	3.2	2.0	1.8	0.29	0.56
11:00 A.M.	8.7	4.3	3.0	2.6	0.34	0.60
12:00 M.	10.0	5.7	2.9	2.5	0.29	0.44
1:00 P.M.	8.2	5.1	2.7	2.4	0.33	0.47
2:00 P.M.	5.8	3.7	2.0	1.8	0.34	0.49
3:00 P.M.	3.6	2.5	1.6	1.4	0.44	0.56
4:00 P.M.	2.8	1.1	1.0	.....	0.36	.....

effect of the cheese-cloth tent, therefore, appears to be not only to reduce the total amount of light available to the plants, but also to transform a large proportion of the direct light into diffuse light. The plants growing within the tent have available for photosynthesis less total light than the plants growing outside, but a larger proportion of this light is diffuse.

TEMPERATURE

The temperatures in each of the two stations were recorded by Fries thermographs placed in shelters so constructed, with double roof and open sides, as to protect the instruments from the direct rays of the sun and from rain without hindering the free circulation of air. The thermographs had been carefully adjusted during a few weeks' trial previous to the beginning of the experiments. After having been placed in the field, they were daily compared with standard thermometers whose bulbs hung near the bellows of the instruments. The thermographs agreed very closely with the thermometers throughout the experiment, and required very little further adjustment.

The average daily temperatures during the course of the experiment were obtained by integrating the records for each day with a planimeter. The results thus obtained, together with the differences between the daily average in the tent and in the open, are given in table III. The records are given in Fahrenheit degrees since the instruments recorded in that scale, but the values have also been calculated in Centigrade degrees, which are given in the last two columns.

Table III shows that there was no marked difference between the temperature within the tent and that outside. The difference was usually less than one degree. Moreover, it was sometimes positive and sometimes negative. The sum of the differences for the total period is only 7°.67 F. The average daily excess of the temperature outside the tent over that inside was therefore approximately 0°.14. This is contrary to the results of STEWART,[5] who found that in the Connecticut Valley the average daily temperature

[5] STEWART, J. B., The effects of shading on soil conditions. U.S. Dept. Agric., Bureau of Soils, Bull. 39. 1907.

TABLE III

AVERAGE DAILY TEMPERATURE

FOR 24 HOURS ENDING AT 4 P.M.	MEAN TEMPERATURE (FAHRENHEIT)		DIFFERENCE	MEAN TEMPERATURE (CENTIGRADE)	
	Open	Shade		Open	Shade
December 4	72.23	.....	.....	22.35	.....
" 5	69.54	70.91	+1.37	20.86	21.62
" 6	75.35	76.14	+0.79	24.08	24.52
" 7	74.54	73.93	−0.61	23.63	23.29
" 8	68.52	69.03	+0.51	20.29	20.57
" 9	71.67	71.12	−0.55	22.04	21.73
" 10	69.68	68.77	−0.91	20.93	20.43
" 11	64.86	61.90	−2.96	18.26	16.61
" 12	62.86	63.56	+0.70	17.14	17.53
" 13	67.03	66.55	−0.48	19.46	19.19
" 14	64.46	64.86	+0.40	18.03	18.25
" 15	67.02	68.13	+1.11	19.46	20.07
" 16	66.85	67.74	+0.89	19.36	19.85
" 17	67.26	68.53	+1.27	19.59	20.29
" 18	64.68	67.40	+2.72	18.16	19.67
" 19	69.00	69.82	+0.82	20.56	21.01
" 20	71.17	72.05	+0.88	21.76	22.25
" 21	67.75	67.60	−0.15	19.86	19.78
" 22	68.90	70.55	+1.65	20.50	21.42
" 23	67.06	67.43	+0.37	19.48	19.68
" 24	65.04	65.10	+0.06	18.36	18.39
" 25	65.34	64.95	−0.39	18.52	18.30
" 26	63.42	63.54	+0.12	17.46	17.52
" 27	58.30	58.45	+0.15	14.61	14.69
" 28	65.76	65.25	−0.51	18.76	18.47
" 29	67.94	67.62	−0.32	19.97	19.79
" 30	72.85	70.51	−2.34	22.69	21.39
" 31	72.00	70.86	−1.14	22.22	21.59
January 1	69.68	68.04	−1.64	20.93	20.02
" 2	68.23	68.01	−0.22	20.13	20.01
" 3	72.13	71.02	−1.11	22.29	21.68
" 4	73.81	72.81	−1.00	23.23	22.67
" 5	72.28	71.78	−0.50	22.38	22.10
" 6	68.62	68.47	−0.15	20.34	20.26
" 7	63.29	62.17	−1.12	17.38	16.76
" 8	62.69	61.39	−1.30	17.05	16.33
" 9	66.67	65.28	−1.39	19.26	18.49
" 10	66.58	66.64	+0.06	19.21	19.24
" 11	65.07	64.80	−0.27	18.37	18.22
" 12	66.89	66.60	−0.29	19.38	19.22
" 13	65.69	65.14	−0.55	18.72	18.41
" 14	71.80	69.51	−2.29	22.11	20.84
" 15	67.50	65.73	−1.77	19.72	18.74
" 16	67.42	67.09	−0.33	19.68	19.49
" 17	65.33	64.13	−1.20	18.52	17.85
" 18	63.84	63.45	−0.39	17.69	17.47
" 19	65.58	67.00	+1.42	18.66	19.44
" 20	66.40	66.37	−0.03	19.11	19.09
" 21	65.96	65.18	−0.78	18.87	17.88

TABLE III—*Continued*

For 24 hours ending at 4 P.M.	Mean temperature (Fahrenheit)		Difference	Mean temperature (Centigrade)	
	Open	Shade		Open	Shade
January 22.....	71.24	70.24	−1.00	21.80	21.24
" 23.....	68.05	68.57	+0.52	20.03	20.32
" 24.....	65.98	66.87	+0.89	18.88	19.37
" 25.....	66.35	66.22	−0.13	19.08	19.01
" 26.....	62.58	64.40	+1.82	16.99	18.00
" 27.....	63.13	64.10	+0.97	17.29	17.83
" 28.....	60.20	60.86	+0.66	15.67	16.03

within a cheese-cloth tent was 1–3° F. higher than that outside. It is possible that the climatic conditions in these two regions are sufficiently different to account for the apparently different effects of the cheese-cloth, but it should be stated that STEWART obtained his average daily temperature from the maximum and minimum temperatures of each day, a method which does not give the true average temperature. It is evident from the data of table III that under the climatic conditions prevailing in Western Cuba during the months of December and January the cheese-cloth tents used for shading tobacco in that region show very little tendency to retain heat.

Relative humidity

The relative humidity in the two stations was recorded by means of Draper hygrometers. These instruments, like the thermographs, had been kept under observation for several weeks previous to the beginning of the experiments, and during that time had been adjusted to correspond through the lower part of their range with a sling psychrometer. Since the range of these instruments was not adjustable, it was not possible to make them correspond with the psychrometer readings through the whole range of the scale. At night, when the sling psychrometer regularly showed a relative humidity of 100 per cent, the hygrometers still showed a deficit of 4–5 per cent. The recording instruments, however, agreed with each other throughout the range of the movement of the pens. Each week during the course of the experiment the instruments were compared by being placed side by side for one hour. They

TABLE IV

AVERAGE DAILY HUMIDITY

FOR 24 HOURS ENDING 4 P.M.	HYGROMETER			SLING PSYCHROMETER		
	Open	Shade	Difference	Open	Shade	Difference
December 1	79.5	79.0	−0.5	.....	.....	.....
" 2	78.5	79.5	+1.0	.....	.....	.....
" 3	79.5	80.0	+0.5	.....	.....	.....
" 4	79.5	80.0	+0.5	.....	.....	.....
" 5	84.5	84.0	−0.5	.....	.....	.....
" 6	78.5	79.0	+0.5	.....	.....	.....
" 7	78.0	78.5	+0.5	.....	.....	.....
" 8	81.0	82.0	+1.0	.....	.....	.....
" 9	81.5	84.0	+2.5	.....	.....	.....
" 10	83.0	85.5	+2.5	86.0	83.6	−2.4
" 11	74.0	77.0	+3.0	46.2	49.0	+2.8
" 12	79.5	81.5	+2.0	47.4	48.6	+1.2
" 13	89.0	91.0	+2.0	86.0	88.6	+2.6
" 14	79.5	82.5	+3.0	49.6	51.4	+1.8
" 15	79.5	83.0	+3.5	51.6	57.4	+5.8
" 16	84.5	86.5	+2.0	59.4	61.6	+2.2
" 17	79.5	81.5	+2.0	53.0	56.8	+3.8
" 18	76.0	77.0	+1.0	46.0	46.6	+0.6
" 19	75.0	78.0	+3.0	44.6	44.8	+0.2
" 20	78.5	78.5	.....	49.0	49.0	.....
" 21	80.0	80.5	+0.5	56.2	54.0	−2.2
" 22	86.0	84.5	−1.5	51.2	53.2	+2.0
" 23	85.5	86.5	+1.0	73.8	73.4	−0.4
" 24	77.5	78.5	+1.0	46.4	47.6	+1.2
" 25	82.5	83.0	+0.5	63.4	63.0	−0.4
" 26	78.0	80.0	+2.0	56.8	61.4	+4.6
" 27	78.0	79.5	+1.5	50.6	52.2	+1.6
" 28	71.0	73.5	+2.5	43.0	44.0	+1.0
" 29	71.0	73.0	+2.0	49.6	52.4	+2.8
" 30	81.0	83.0	+2.0	66.4	70.2	+3.8
" 31	86.0	85.5	−0.5	75.4	77.4	+2.0
January 1	86.5	86.0	−0.5	78.0	79.2	+1.2
" 2	84.0	84.0	.....	62.4	62.4	.....
" 3	82.0	82.0	.....	64.0	68.4	+4.4
" 4	81.5	83.0	+1.5	64.0	63.6	−0.4
" 5	87.5	88.5	+1.0	73.2	73.8	+0.6
" 6	79.5	81.0	+1.5	57.8	57.8	.....
" 7	78.0	80.0	+2.0	61.4	63.4	+2.0
" 8	81.0	83.0	+2.0	65.6	71.2	+5.6
" 9	85.5	87.5	+2.0	78.4	78.8	+0.4
" 10	74.5	79.5	+5.0	47.4	54.0	+6.6
" 11	74.0	77.0	+3.0	45.8	54.4	+8.6
" 12	70.0	74.0	+4.0	43.0	50.2	+7.2
" 13	71.5	77.0	+5.5	42.4	48.4	+6.0
" 14	75.0	78.5	+3.5	55.6	59.6	+4.0
" 15	78.0	83.0	+5.0	65.2	70.6	+5.4
" 16	77.5	81.5	+4.0	58.2	58.4	+0.2
" 17	77.5	80.5	+3.0	60.4	66.2	+5.8
" 18	83.0	86.0	+3.0	67.0	69.4	+2.4
" 19	77.5	82.0	+4.5	46.0	50.2	+4.2
" 20	77.0	80.5	+3.5	53.6	63.2	+9.6

TABLE IV—*Continued*

For 24 hours ending 4 P.M.	Hygrometer			Sling psychrometer		
	Open	Shade	Difference	Open	Shade	Difference
January 21.....	77.0	80.5	+3.5	50.8	57.8	+7.0
" 22.....	76.5	80.0	+3.5	48.4	58.2	+9.8
" 23.....	80.0	83.0	+3.0	57.2	66.4	+9.2
" 24.....	78.5	82.5	+4.0	58.2	62.8	+4.6
" 25.....	76.0	80.0	+4.0	50.2	54.4	+4.2
" 26.....	77.0	80.5	+3.5	52.0	60.0	+8.0
" 27.....	77.0	80.0	+3.0	53.8	56.8	+3.0
" 28.....	74.0	78.5	+4.5	50.0	54.8	+4.8

were readjusted only once during the entire time. To overcome the effects of accidental differences not detected the hygrometers of the two stations were interchanged each week. From what has been said it will be clear that only a relative value can be ascribed to the humidity records. Since the two instruments agreed with each other when kept under the same conditions, this record, nevertheless, ought to give a fair idea of the differences in relative humidity inside and outside the tent. The daily averages were obtained by integrating the curves of the records (which are on circular charts) by means of a Bristol-Durand radii-averaging instrument. These averages, together with the differences between the figures for the two stations for each day, are given in table IV. In addition to the hygrometer records, daily observations were taken at noon in the two stations by means of a sling psychrometer. The results of these observations are given in the fourth and fifth columns of the table, where each figure represents the average of five readings. These observations taken at noon represent approximately the lowest relative humidity for each day.

Table IV shows that the relative humidity is higher inside than outside the tent, but the difference is not as great as that found by Stewart in Connecticut. Owing to the greater quantities of water given off by the plants with increase in leaf surface during growth, the difference is greater toward the end of the season than at the beginning. This relation is brought out still more strikingly by the differences during the day, when the plants are actively transpiring. The difference in the relative humidity inside and

outside the tent at noon is much greater than the difference in the average relative humidity of the two stations.

Evaporation

Records of the relative rates of evaporation in the two stations were obtained by means of the porous cup atmometer described by LIVINGSTON[6] and since frequently used in studies dealing with the relation between plant functions and meteorological conditions.

TABLE V

EVAPORATION FROM POROUS CUP ATMOMETERS

Date	Open	Shade	Date	Open	Shade
December 2	19.9 cc.	15.5 cc.	December 31	9.7 cc.	4.2 cc.
" 3	16.4	12.4	January 1	8.1	4.3
" 4	10.8	10.0	" 2	12.6	6.5
" 5	12.7	9.2	" 3	12.2	7.8
" 6	22.5	16.2	" 4	12.0	6.4
" 7	18.2	12.8	" 5	5.5	1.8
" 8	15.6	12.0	" 6	13.6	8.3
" 9	14.4	10.6	" 7	14.1	6.8
" 10	15.6	11.3	" 8	12.5	6.0
" 11	22.3	16.4	" 9	6.2	2.4
" 12	17.0	12.6	" 10	18.5	8.5
" 13	1.4	0.0	" 11	19.8	8.5
" 14	14.8	10.7	" 12	22.7	10.0
" 15	18.3	13.5	" 13	19.4	8.1
" 16	14.1	10.8	" 14	21.3	9.3
" 17	21.0	15.2	" 15	15.5	6.2
" 18	25.2	16.7	" 16	13.8	5.9
" 19	22.1	16.0	" 17	14.8	5.7
" 20	22.1	15.7	" 18	6.8	1.7
" 21	16.6	12.1	" 19	13.6	5.4
" 22	13.8	9.5	" 20	14.4	5.7
" 23	11.7	7.0	" 21	14.6	6.1
" 24	20.2	13.3	" 22	15.8	7.1
" 25	16.3	11.1	" 23	13.8	6.1
" 26	20.7	12.3	" 24	12.8	6.0
" 27	21.1	13.3	" 25	15.3	7.4
" 28	30.3	18.3	" 26	13.8	6.6
" 29	16.4	16.8	" 27	13.8	6.2
" 30	13.0	8.0	" 28	14.4	6.6
Total				905.9	540.9

The instruments were set up in such a manner that the cups were about one meter above the ground, the water being supplied to the cups by means of burettes. With the growth of the surrounding plants the cups were partly shaded, but this was not considered

[6] LIVINGSTON, B. E., A simple atmometer. Science N.S. **28**:319, 320. 1908; see also Plant World **15**:157–162. 1912.

disadvantageous, since the cups were thus probably exposed to nearly the same average conditions of light and shade as the leaves. The record of evaporation from the cups during the course of the experiments is given in table V. The figures are all reduced to terms of evaporation from a standard atmometer whose coefficient is taken as unity. They are directly comparable, therefore, with each other and with the figures given by LIVINGSTON[7] and by CALDWELL.[8]

Table V shows that the rate of evaporation is constantly less under the cheese-cloth cover than it is in the open. As with the relative humidity, the difference between the two stations increases with the development of the plants. During the early part of the period covered by the experiments, the cups in the open lost one-fourth to one-third more water than those in the shade, but later the loss from the cups in the open was more than twice that from those in the shade. The increasing divergence of the rates of evaporation corresponds with the increasing quantity of water vapor given off by the growing plants.

Rainfall

As a rule, there is very little rainfall in Western Cuba in the winter months, during which the tobacco crop is grown, consequently tobacco and other crops grown during that season require irrigation. The season during which this experiment was conducted was no exception. The only rather heavy rains occurred on December 13 and December 15, and on January 5. The complete record of rainfall taken from the weather observations at the station during the time of the experiment is as follows:

December	2.....	3.30 mm.	January	1.....	1.02 mm.
"	8.....	3.81 "	"	2.....	0.76 "
"	13.....	11.68 "	"	4.....	1.02 "
"	15.....	7.37 "	"	5.....	12.58 "
"	30.....	1.78 "	"	8.....	1.52 "
"	31.....	1.02 "	"	19.....	0.51 "

[7] LIVINGSTON, B. E., A study of the relation between summer evaporation intensity and centers of plant distribution in the United States. Plant World 14:205–222. 1911.

[8] CALDWELL, J. S., The relation of environmental conditions to the phenomena of permanent wilting in plants. Physiol. Researches 1:1–56. 1913.

Summary of observations on environment

The data relating to the changes in the environment induced by the cheese-cloth shade may be briefly summed up here.

The light intensity is greatly modified by the cheese-cloth shade. The total light under the cloth is reduced by about one-third, but the diffuse light inside the tent is only slightly reduced. It appears, therefore, that the plants inside the tent receive a smaller quantity of total light than the plants outside, but an almost equal amount of diffuse light.

The cheese-cloth tent shows very little effect on the temperature. On the whole, the temperature outside the tent is slightly higher than that inside. The average difference for the 60 days, however, is only about 0°.14 F. This can have but little effect on the transpiration of the plants. It appears that any tendency of the tent to retain heat is compensated by the reduced amount of radiant energy which passes into the tent.

The difference in the relative humidity of the two stations is much greater than the difference in temperature. This difference is restricted to the hours of sunlight, for at night the relative humidity in both stations reaches 100 per cent. During the day the difference is enhanced by the partial retention by the tent of the water transpired by the plant.

The rate of physical evaporation is greater in the open than under the cheese-cloth shade. The divergence of the rates of evaporation in the two stations increases with the development of the plants and the consequent increase in relative humidity under the cheese-cloth.

Aside from the lessening of the illumination and the increase in relative humidity, the cheese-cloth effects a reduction of air currents. All these changes tend to diminish transpiration.

Materials and methods of experimentation

The plants used in this work were grown from seed obtained during the previous season from a single self-fertilized mother-plant, whose offspring was shown by subsequent cultivation both in Cuba and in the United States to be of a pure strain.[9] From a

[9] The strain used was the no. 7 described in the following paper: HASSELBRING, H., Types of Cuban tobacco. BOT. GAZ. **53**:113–126. *pls. 4–10.* 1912.

large number of seedlings, 12 were selected as uniform as possible. The experimental plants were grown in cylindrical galvanized iron tanks 38 cm. high and 30.5 cm. in diameter. These tanks resembled in general construction those described by FORTIER.[10] Each tank was provided with an inlet tube 1.3 cm. in diameter, which ran down the inside of the tank to the center of the bottom where it ended. The upper end of the tube was closed by a screw cap. Each tank was further provided at the rim with two lugs into which hooks could be inserted to facilitate lifting and carrying the tanks. These tanks were fitted into others just large enough to receive them, which were permanently sunk in the ground. To prevent the soil from falling into the space between the walls of the two tanks, the inner tanks were provided near the rim with annular flanges which projected over the rims of the outer tanks. In order to prevent rain water from reaching the soil in the tanks, they were fitted with covers made in two parts, with flanges interlocking in such a way that water could enter only through the opening around the stem of the plant. This was closed as effectually as possible by means of thin sheet rubber. The covers were placed on the tanks every night and during threatening weather.

The soil used for filling the tanks was taken from a well-tilled field which in former years had been used for growing tobacco and other crops. A quantity, somewhat more than sufficient for filling the tanks, was placed on the concrete floor of a closed shed, where it was thoroughly worked over many times, with the addition of successive small quantities of water until the whole mass was brought into a moist, friable condition. The soil was left in a pile for a day to allow the moisture to become uniformly distributed throughout the mass. On the following day it was again worked over several times and run through a screen preparatory to the filling of the tanks.

Before the tanks were filled, a layer of broken stone was placed on the bottom of each in order to form a sort of reservoir for water and to prevent the closing of the inlet tube by the soil. By means of the stones the tanks were all brought to the same tare. They were then filled with soil which was tamped as uniformly as possible

[10] FORTIER, S., Evaporation losses in irrigation and water requirements of crops. U.S. Dept. Agric., Office of Exp. Stations, Bull. 177. 1907.

to give it the same compactness as the soil of the field. Thirty kilograms of soil were put into each can.

The seedlings which had 3 or 4 small leaves were planted in the tanks on November 27, 1908. At that time each plant was given 500 cc. of water at the surface, and 1000 cc. were added to each tank through the inlet tube. The tanks were left under cover of the shed until the following day (November 28), when all the plants had completely recovered from the effects of transplanting. The tanks were then given another liter of water through the inlet tube and enough more was added to those that required it to bring them all to the same weight.

One set of six tanks with plants, and three without plants that had been treated in every way like those containing plants, was placed in two rows among the plants of the regular crop under the cheese-cloth which covered an area of one hectare (2.471 acres). The other similar set was placed in like manner in an adjoining field of one hectare also planted with tobacco. The sets of experimental plants were thus subjected to the same conditions in their respective environments as the plants of the regular crop.

The general development of the experimental plants was in every way normal, and did not differ from that of those among which they stood. The axillary buds were removed as soon as they appeared, so that the plants grew to a single stem without branches. The terminal buds were not removed, however, as is customary in commercial practice.

The shade plants attained a nearly uniform height of 2.1 meters, while the height of the sun plants, which were a little less uniform, averaged about 1.75 meters. The leaves of the shade plants were much larger and thinner than those of the sun plants and the internodes of the stems were longer.

During the course of the experiment the original seedling leaves, which had increased much in size, withered. These were cut off and dried and later were ground up with the rest of the plants from which they had been taken.

In spite of the tamping of the soil in the tanks, it was found that the soil water receded from the upper layers of soil, which became very dry. Whenever this condition led to incipient wilting, the

proper state of moisture was restored by adding measured quantities of water at the surface, the controls being treated in the same way. In all, five liters of water were thus added from November 27 to January 14.

From the time that the tanks were placed in the field, the loss of water from the soil and plants was determined by daily weighings. For these weighings a small platform scale specially constructed for the purpose was used. This scale was equipped with agate bearings and with two riders which could be clamped at any point on the beams, one of which was graduated in units of one gram for the smaller rider. The end of the beam was provided with a pointer which indicated the position of exact balance. The scale was sensitive to one gram with the load of 35 kilograms, approximately the weight of the tanks when filled. It was placed permanently on a low solid platform in a shelter to which the tanks could be conveniently brought. The water lost from the soil and plants was replaced each day by the addition of enough water through the inlet tubes to bring the tanks up to the standard weight. While the plants were small, the quantity of water thus added was measured from a burette, but later, when the daily transpiration was large, the bulk of the water required was added by means of graduated flasks marked for pouring, only the final fractions being run in from the burette. The operation was begun at 4:00 P.M. each day and required about two hours for its completion. The quantity of water thus added was recorded as the daily loss by transpiration from the plants and evaporation from the soil.

For obtaining the total transpiration of the plants, the average quantity lost from the three control tanks was subtracted from the total quantity lost from each of the other tanks in the same station, the loss from the controls being regarded as representing the quantity lost from the soil of the tanks containing plants. The difference caused by the partial shading of the soil of the planted tanks had to be disregarded.

The plants were harvested on January 28, at about the time of maturity of the general crop. At that time the leaves were fully grown and the inflorescence was well developed, a few flowers having opened.

The leaves with their decurrent wings were first cut from each plant and weighed immediately. Thereupon, prints for determining the leaf area were made on blue-print paper. The stems, including the inflorescence, were cut off at the surface of the ground, weighed, and cut into small pieces for drying. In order to obtain the roots, the soil was washed out of the tanks with a stream of water. With the aid of a brush the roots were washed free from adhering soil particles. They were then dried by being pressed between towels and absorbent paper, weighed, and cut up for drying.

To obtain the weight of dry substance, the fresh material was dried at 60–70° C. and ground in a drug mill with the observance of such precautions that the material was quantitatively recovered. The leaves, stems, and roots of each plant were ground separately. The air-dry material thus obtained was weighed, and from each lot four samples of approximately 2 grams each were taken. These were dried to a constant weight in a slow current of hydrogen at a pressure of 6 cm. of mercury and a temperature of 78° C.

In order to make a comparison of the transpiration per unit area of leaf surface for the plants in the two stations, the leaf prints made at the time of harvesting were cut out and weighed, and their area was calculated from the relation of their weight to the weight and total area of the original paper. As a basis for calculating the transpiration per unit area of leaf surface, the average quantity of water transpired during the last five days of the experiment was taken. Since the plants had reached the flowering stage, it may be assumed that there was very little change of area of the leaves during this period. The taking of the average daily transpiration obviated to a certain extent peculiarities which might be exhibited by the transpiration of a single day.

Data

In connection with the presentation of the data, attention may again be called to the fact that the plants used in these experiments were the descendants of a single self-fertilized mother plant whose progeny was shown by subsequent cultivation during two generations to be of a pure strain. For this reason more confidence can

be placed in the results than would be possible if the plants had been selected from an indiscriminate mixture. The result of this selection was manifested in the uniform growth of the plants in each of the two stations. The data relating to the total transpiration of the two sets of plants are given in table VI.

TABLE VI

WATER TRANSPIRED BY PLANTS DURING 60 DAYS OF GROWTH

OPEN			SHADE		
No. of plant	Total water transpired	Water transpired per gram of water-free substance produced	No. of plant	Total water transpired	Water transpired per gram of water-free substance produced
1.....	51,256 cc.	245.21 cc.	10.....	41,117 cc.	194.47 cc.
3.....	41,328	245.52	12.....	37,308	187.40
5.....	45,959	239.48	14.....	35,494	192.20
6.....	44,665	237.62	15.....	33,025	191.38
7.....	45,625	246.54	16.....	32,935	176.31
9.....	44,402	235.93	18.....	31,396	180.16
Average	45,539	241.72	Average....	35,212	186.99

Table VI shows that the sun plants transpired on the average 10 liters (about 30 per cent) more water per plant than the shade plants. Although the figures show considerable fluctuation in transpiration among the individuals of each set, yet if the plants of the two sets are compared in the order of magnitude of their transpiration, it will be found that the difference between the members of the different series is practically the same as the difference between the averages for the whole series. Since the average weight of dry matter produced was the same in the two sets of plants, it follows that the series having the higher total transpiration also has the highest transpiration per gram of dry plant substance. This is substantiated by the figures which show that the shade plants transpired 186.99 cc. of water for the production of one gram of plant substance, while the sun plants transpired 241.72 cc. for one gram, or about 30 per cent more than the shade plants. The quantity of water transpired per unit of dry matter produced is remarkably uniform for the plants within each group. A similar close agreement between the quantities of water transpired per unit

The leaves with their decurrent wings were first cut from each plant and weighed immediately. Thereupon, prints for determining the leaf area were made on blue-print paper. The stems, including the inflorescence, were cut off at the surface of the ground, weighed, and cut into small pieces for drying. In order to obtain the roots, the soil was washed out of the tanks with a stream of water. With the aid of a brush the roots were washed free from adhering soil particles. They were then dried by being pressed between towels and absorbent paper, weighed, and cut up for drying.

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9.....	44,402	235.93	18.....	31,396	180.16
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Table VI shows that the sun plants transpired on the average 10 liters (about 30 per cent) more water per plant than the shade plants. Although the figures show considerable fluctuation in transpiration among the individuals of each set, yet if the plants of the two sets are compared in the order of magnitude of their transpiration, it will be found that the difference between the members of the different series is practically the same as the difference between the averages for the whole series. Since the average weight of dry matter produced was the same in the two sets of plants, it follows that the series having the higher total transpiration also has the highest transpiration per gram of dry plant substance. This is substantiated by the figures which show that the shade plants transpired 186.99 cc. of water for the production of one gram of plant substance, while the sun plants transpired 241.72 cc. for one gram, or about 30 per cent more than the shade plants. The quantity of water transpired per unit of dry matter produced is remarkably uniform for the plants within each group. A similar close agreement between the quantities of water transpired per unit

of dry matter produced by plants growing in different nutrient solutions has recently led MAZÉ[11] to conclude that under the same aerial conditions the quantity of water transpired per unit of dry matter produced is constant and independent of the nature of the nutritive solutions or of their concentrations or of the state of development of the plant. It is needless to state that this conclusion could hold good only for solutions which contain all the necessary nutrients and which are not otherwise injurious to the growth of plants.[12]

TABLE VII

TRANSPIRATION PER SQ. DM. OF LEAF SURFACE DURING LAST FIVE DAYS OF GROWTH

No. of plant	Leaf area in sq. cm. both surfaces	Total transpiration for last five days in cc.	Transpiration per sq. dm. of leaf surface in cc.	Average hourly transpiration per sq. dm. leaf surface in cc.
OPEN				
1	22,026	10,941	49.67	0.414
3	19,454	10,158	52.22	0.435
5	23,550	11,230	47.69	0.397
6	20,335	10,376	51.02	0.425
7	21,300	10,936	51.34	0.428
9	21,989	9,755	44.36	0.370
Average	21,442	10,566		0.412
SHADE				
10	27,896	8,658	31.04	0.259
12	27,461	8,332	30.34	0.253
14	29,026	8,791	30.29	0.252
15	29,116	6,930	23.80	0.198
16	31,163	7,236	23.22	0.194
18	31,867	7,224	22.67	0.189
Average	29,442	7,862		0.224

The relative transpiration per unit area of leaf surface is given in table VII. As has been stated, the figures are based on the transpiration of the last five days. This table brings out the relative leaf areas of the plants grown under the two conditions. The

[11] MAZÉ, Sur la relation qui existe entre l'eau évaporée et le poids de matière végétale élaborée par le maïs. Compt. Rend. **156**:720–722. 1913.

[12] That other conditions, such as deficiency or excess of mineral nutrients, may limit production while transpiration continues has been frequently pointed out in agricultural literature: HELLRIEGEL, H., Beiträge Naturwiss. Grundlagen Ackerbaus Braunschweig. pp. 628–635; VON SEELHORST, Jour. Landw. **47**:369–378. 1899.

average leaf area per plant of those grown in the shade was 8000 sq. cm. greater than that of the plants grown in full light. Yet, as we have seen, in spite of this great difference in leaf area, the shade plants used about 10 liters of water less per plant than the sun plants. The hourly transpiration per unit of leaf surface was nearly 84 per cent greater in the plants in the open. The actual hourly transpiration was probably double that given in the tables, since the calculation was based on a 24-hour day, while the plants did not transpire perceptibly during at least 12 hours of that time. Such a change would not, however, alter the relative value of the figures which chiefly concern us here.

A comparison of the rates of transpiration from the leaves during the last five days with the rates of evaporation from the porous cups during the same period of time shows a fairly close relative agreement between transpiration and physical evaporation. The ratio of transpiration in the shade to that in the open is 1:1.8; while the ratio of evaporation from the atmometers in the two stations is 1:2.1.

The data relating to the fresh weight of the plants are given in table VIII.

TABLE VIII

FRESH WEIGHT OF PLANTS

No. of plant	Leaves	Stems	Roots	Total
OPEN				
1	409	364	246	1019
3	365	335	199	899
5	433	407	233	1073
6	371	388	182	941
7	412	398	197	1007
9	416	389	215	1020
Average	401	380	212	993
SHADE				
10	451	508	257	1216
12	443	494	210	1147
14	467	479	193	1139
15	461	466	186	1113
16	488	483	203	1174
18	502	503	180	1185
Average	469	489	205	1162

The average weight of the shade plants was nearly 170 grams greater than that of the sun plants. Moreover, there was no aberrant case. The members within each group were fairly uniform, but all of the shade plants had a greater weight than any of the sun plants. The distribution of the material within the plants is worthy of note. Here also the results, in whatever direction they point, are true as well for a comparison of the individual plants of the respective groups with each other as for a comparison of the general averages. The average weight of the leaves of the shade plants was 68 grams higher than that of the sun plants, while the difference in the stems was still greater, the difference here being over 100 grams in favor of the shade plants. The fresh weight of the root-systems of the two groups of plants was about the same in both. These relations are especially interesting when considered in connection with the weight and distribution of dry matter in the plants as shown in table IX.

TABLE IX

WEIGHT OF WATER-FREE SUBSTANCE OF PLANTS

No. of plant	Leaves	Stems	Roots	Total
OPEN				
1	82.54	73.09	53.40	209.03
3	67.36	59.72	41.25	168.33
5	75.01	69.71	47.19	191.91
6	74.32	70.76	42.89	187.97
7	74.35	67.62	43.09	185.06
9	73.40	71.05	43.75	188.20
Average	74.50	68.66	45.26	188.42
SHADE				
10	71.61	90.36	49.46	211.43
12	69.67	82.92	46.49	199.08
14	66.42	78.08	40.17	184.67
15	59.61	74.22	38.73	172.56
16	71.65	76.19	38.96	186.80
18	62.69	76.32	35.26	174.27
Average	66.94	79.68	41.51	188.14

While the average fresh weight of the shade plants was nearly 170 grams greater than that of the sun plants, the average dry

weight of the two sets was the same, approximately 188 grams. A more marked contrast even is brought out by a comparison of the distribution of material in the different organs of the plants. The weight of dry substance in the roots was practically identical in the two groups. The stems of the shade plants contained 18 per cent more dry matter than those of the sun plants, but the leaves of the sun plants contained 11 per cent more material than the leaves of the shade plants, although the average total area of shade leaves, as shown in table VII, was 37 per cent greater than that of the sun leaves. To recapitulate, the fresh weight of the shade plants was higher than that of the sun plants. This statement applies also to the leaves and stems when the organs are considered separately, but not to the roots, which were about equal in the two sets. The average dry weight of the whole plants and of the roots was the same in the two sets of plants; but the weight of dry material in the leaves was greater for the sun plants, while that of the stems was greater for the shade plants.

These facts show that on the whole the water content of the

TABLE X

PERCENTAGE OF WATER IN LEAVES, STEMS, AND ROOTS

No. of plant	Leaves	Stems	Roots	Total
OPEN				
1	79.82	79.92	78.29	79.49
3	81.55	82.17	79.27	81.28
5	82.68	82.87	79.75	82.11
6	79.97	81.76	76.43	80.02
7	81.95	83.01	78.13	81.62
9	82.36	81.74	79.65	81.55
Average	81.39	81.91	78.59	81.01
SHADE				
10	84.12	82.21	80.75	82.61
12	84.27	83.21	77.86	82.64
14	85.78	83.70	79.19	83.79
15	87.07	84.07	79.18	84.50
16	85.32	84.23	80.81	84.09
18	87.51	84.83	80.41	85.29
Average	85.68	83.71	79.70	83.82

shade plants was greater than that of the sun plants.[13] The figures of table X bear out this relationship, not only with regard to the plants as a whole, but also with regard to the individual organs. The complete data are given in that table.

As might be expected, the greatest difference in water content was found in the leaves, whereas the water content of the roots was about equal in the two groups. In the stems, in spite of the fact that the higher fresh weight corresponds with the higher dry weight, the shade plants, nevertheless, contained the greater percentage of water.

General discussion

Various views have been held as to the relation between transpiration and the production of plant substance, or the influence of these processes upon each other. As early as 1850, LAWES[14] expressed the belief that although the whole subject was as yet a problem, a certain relationship existed between evaporation and rapidity of growth, in that the comparative rate of evaporation of water to some extent indicated the comparative activity of the processes of the plants. He was too cautious an investigator, however, to conclude more than that his experiments indicated some definite relationship between the passage of water through the plant and the production of dry matter. A somewhat similar idea was expressed by FITTBOGEN.[15] HELLRIEGEL[16] in discussing this subject pointed out that, although the curves of growth and of transpiration follow the same general course, they are never parallel or coincident. He considered the dry substance produced merely as a convenient empirical basis from which to reckon the water-utilization of plants. As a result of his experiments, which how-

[13] This fact should be taken into consideration in the curing of shade-grown tobacco.

[14] LAWES, J. B., Experimental investigation into the amount of water given off by plants during their growth; especially in relation to the fixation and source of their various constituents. Jour. Hort. Soc. London **5**:38–63. 1850.

[15] FITTBOGEN, J., Altes und Neues aus dem Leben der Gerstenpflanze. Landw. Vers.-Stationen **13**:81–136. 1871.

[16] HELLRIEGEL, H., *op. cit.* pp. 622–623. 1883.

ever are open to criticism, he concluded that transpiration had no effect on the production of plant substance.[17]

A somewhat unusual standpoint was taken by SORAUER,[18] who regarded transpiration not merely as a mechanical process, but as a physiological function in the sense that it depends upon other physiological processes of the plant. According to him, outer factors do not influence transpiration directly, but only through their action on other functions of the plant.

A relation not less intimate, but in its nature the converse of that conceived by SORAUER, is that which KOHL[19] believed to exist between transpiration and assimilation. He described the influence of transpiration upon assimilation essentially as follows: A rapidly transpiring plant receives, by means of the transpiration stream, a greater abundance of mineral nutrients, and is thereby enabled to produce more organic matter than a plant with lower transpiration. It should be said that KOHL's assumption was based purely on anatomical observations and not on comparative quantitative determinations. Increased transpiration does not necessarily bring about a greater abundance of mineral matter in plants.[20] A close correlation between transpiration and growth has recently been observed also by LIVINGSTON[21] in wheat seedlings during the early stages of their development.

Although in general the conclusion derived from the work of these authors is that transpiration and assimilation are correlated or at most that transpiration has no influence on production, experiments leading to an opposite conclusion are not wanting.

As early as 1869 SCHLOESSING[22] found that a tobacco plant growing under a shaded bell jar produced more dry leaf substance

[17] HELLRIEGEL, H., *op. cit.* pp. 461–501.

[18] SORAUER, P., Der Einfluss der Luftfeuchtigkeit. Bot. Zeit. **36**:1–13, 17–25. 1878; also Studien über Verdunstung. Forschungen Gebiete Agrikultur-Physik. **3**:351–490. 1880.

[19] KOHL, F. G., Die Transpiration der Pflanzen. pp. 90–116. 1886.

[20] HASSELBRING, H., The relation between the transpiration stream and the absorption of salts. BOT. GAZ. **57**:72, 73. 1914. A complete account of this work will appear later.

[21] LIVINGSTON, B. E., Relation of transpiration to growth in wheat. BOT. GAZ. **40**:178–195. 1905.

[22] SCHLOESSING, TH., Végétation comparée du tabac sous gloche et à l'air libre. Ann. Sci. Nat. Bot. V. **10**:366–369. 1869.

than plants grown in the open; but this experiment is open to several objections, not the least of which is that only the leaves were taken into consideration.

TSCHAPLOWITZ,[23] who gave considerable attention to the effect of transpiration on production, found in many of his experiments an increased production of dry substance as the result of decreased transpiration. From a consideration of these results in connection with those of others,[24] who according to him have found that an excessive depression of transpiration results in a lowering of assimilatory activity, he was led to the conclusion that there exists for plants an optimum magnitude of transpiration; and that if the transpiration exceeds, provided the turgor is always maintained, or falls short of the optimum, it is not possible for the plant to reach the maximum production of which it is innately capable. He regards transpiration as essentially a physical process, the magnitude of which may vary within wide limits without seriously disturbing the character of the processes in the plant, although there may be marked effects on the quantitative results of these processes, that is, on the quantity of the assimilatory products formed.

More decisive are the results of WOLLNY,[25] who grew plants of barley, vetch, alfalfa, flax, and potato under conditions giving three degrees of humidity, and found that with an increase in the degree of humidity there was an increase in the production both of the absolute quantity of fresh material and of dry matter. These experiments seem to indicate that a depression of transpiration results in an increase in the assimilatory activity of the plants.

In the experiments reported in this paper, the plants growing in the open transpired about 10 liters per plant or nearly 30 per cent more water than those grown under shade, yet in spite of this differ-

[23] TSCHAPLOWITZ, F., Über den Einfluss der Blattenflächen, des Zuwachses und der Temperature auf die Verdunstung der Pflanzen. Wiener Obst- und Garten-Zeitung **2**:127–132, 169–175, 222–228. 1877; Landw. Vers.-Stat. **23**:74. 1879 (abstract of address without title); Unters. ü. d. Einwirkung Wärme u. d. a. Formen d. Naturkräfte a. d. Vegetations-Erscheinungen. pp. 1–14. Leipzig, 1882; Gibt es ein Transpirations-Optimum? Bot. Zeit. **41**:352–362. 1883; Untersuchungen über die Wirkung klimatischen Faktoren auf das Wachsthum der Kulturpflanzen. Forschungen Gesamt Gebiet Agrikultur-Physik. **9**:117–145. 1886.

[24] The authorities are not given.

[25] WOLLNY, W., Untersuchungen über den Einfluss der Luftfeuchtigkeit auf das Wachsthum der Pflanzen. Inaug. Diss. Halle. 1898.

ence in transpiration the total quantity of dry substance produced was the same in both sets of plants. This fact suggests that transpiration in itself, or the mere passage of water through the plant, has no influence on assimilatory activity provided the water supply does not fall below a certain minimum required to maintain the turgor of the cells.[26]

There is another factor, however, to be taken into consideration in the discussion of the effect of transpiration on assimilation in these experiments. This factor is the reduced illumination to which the plants under cheese-cloth were subjected. The work of many investigators[27] has shown that for many plants in northern latitudes light can be considerably reduced without reducing the assimilatory activity.[28] An explanation of this fact is furnished by BLACKMAN and MATTHAEI,[29] who believe that under natural conditions leaf temperature and the partial pressure of carbon dioxide

[26] See footnote 12.

[27] TIMIRIAZEFF, C., The cosmical functions of the green plants. Proc. Roy. Soc. **72**:424–461. *pls.* 3. 1904.

BROWN, H. T., and ESCOMBE, F., Researches on some of the physiological processes of green leaves, with special reference to the interchange of energy between the leaf and its surroundings. Proc. Roy. Soc. B **76**:29–111. 1905.

BLACKMAN, F. F., Optima and limiting factors. Ann. Botany **19**:281–295. 1905.

LUBIMENKO, W., Production de la substance sèche et de la chlorophylle chez les végétaux supérieurs aux différentes intensités lumineuses. Ann. Sci. Nat. Bot. IX. **7**:321–415. 1908.

COMBES, R., Détermination des intensités lumineuses optima pour les végétaux aux divers stades de développement. Ann. Sci. Nat. Bot. IX. **11**:75–249. 1910.

ROSÉ, E., Énergie assimilatrice chez les plants cultivées saus différents eclaircments. Ann. Sci. Nat. Bot. IX. **17**:1–110. 1913.

SHANTZ, H. L., The effects of artificial shading on plant growth in Louisiana. U.S.D.A., Bur. Pl. Industry, Bull. 279. 1913. In this paper the data refer to fresh weights of the plants.

[28] In this connection it is interesting to note that SHANDER attributes the beneficial effects of Bordeaux mixture other than those that can be ascribed to its action as a fungicide to the shading produced by the coating on the leaves. Such beneficial action occurs, however, only during bright weather; during cloudy weather the effect of shading is injurious. SHANDER, R., Über die physiologische Wirkung der Kupferntriolkalkbrühe. Landw. Jahrb. **33**:517–584. 1901; see also EWERT, R., Der wechselseitige Einfluss des Lichtes und der Kupferkalkbrühen auf den Stoffwechsel der Pflanze. Landw. Jahrb. **34**:233–310. *pls.* 3. 1905, and Weitere Studien über die physiologische und fungicide Wirkung der Kupferbrühen bei krautigen Gewächsen und der Johannisbeere. Zeitschr. Pflanzenkrank. **22**:257–285. 1912.

[29] BLACKMAN, F. F., and MATTHAEI, Miss G. L. C., A quantitative study of carbon-dioxide assimilation and leaf temperature in natural illumination. Proc. Roy. Soc. B **76**:402–460. 1905.

function as limiting factors for photosynthesis, while light is usually present in excess.

It is evident from the writer's experiments that the reduction of light did not result in a lowering of the total production of plant substance; nevertheless, the production for equal areas of leaf surface was lower in the shade leaves than in the sun leaves. The reduction in photosynthesis in the shade leaves was compensated by an increase in leaf area, so that total production was not diminished.

Although shading, and the conditions brought about thereby, had no influence on the total elaboration of dry substance, the distribution of dry substance was greatly affected. The distribution of the total dry matter among the various organs of the two sets of plants was as follows:

TABLE XI

	Leaves	Stems	Roots
Sun plants.....	40 per cent	36 per cent	24 per cent
Shade plants.....	36 per cent	42 per cent	22 per cent

The proportion of material deposited in the roots was about the same in the two sets of plants, but the proportion deposited in the leaves was much greater for the sun plants than for the shade plants, although the area of the shade leaves was nearly one-third greater than that of the sun leaves. This condition is in accordance with the general observation that rapidly transpiring leaves are thicker and of firmer structure than leaves developed under conditions of lower transpiration; or, as conversely expressed by SORAUER,[30] of equal weights of fresh leaf substance that portion containing the greater percentage of dry matter transpires the more rapidly. The condition in the stems was the reverse of that in the leaves. In the shade plants the stems contained 42 per cent of the total dry matter of the plant, while in the sun plants only 36 per cent was deposited in the stems. It appears, therefore, that the shading exercises a distinct influence on the deposition of material in the stems and leaves, but that the influence affects the two organs

[30] SORAUER, P., *op. cit.* p. 391.

in an opposite manner; and that little or no influence is exerted on the deposition of material in the roots.

From a practical standpoint the reduced transpiration effected by the cheese-cloth shade is of importance in regions like Western Cuba, where, as has been stated, most of the tobacco is grown with the aid of hand irrigation; but important as is this direct saving of water, it is probably not so significant as the effect of the cheese-cloth shade in reducing the loss of moisture from the soil, and thus increasing the moisture content of the upper layers.[31] The importance of this effect is shown by the investigations of WOLLNY,[32] and of MITSCHERLICH,[33] and particularly by the long series of researches of VON SEELHORST[34] and his co-workers which show that the yield of crop increases with an increase of the degree of saturation at which the soil is maintained; according to MITSCHERLICH, even to complete saturation.

[31] STEWART found in Connecticut that the moisture content of the soil was always higher under the cheese-cloth than in the open ground. STEWART, J. B., *op. cit.* In the writer's experiments the control tanks under the shade lost respectively 3865, 3932, and 3698 cc.; while those in the open lost 4495, 4525, and 4549 cc. of water.

[32] WOLLNY, E., Untersuchungen über den Einfluss der Wachstums-Factoren auf das Productionsvermögen der Kulturpflanzen. Forsch. Agrik.-Physik. **20**:53–109. 1897–1898.

[33] MITSCHERLICH, E. A., Das Wasser als Vegetationsfactor. Landw. Jahrb. **42**:701–717. 1912.

[34] TUCKER, M., und VON SEELHORST, C., Der Einfluss, welchen der Wassergehalt und der Reichtum des Bodens auf die Ausbildung der Wurzeln und der oberirdischen Organe der Haferpflanze ausüben. Jour. Landswirtsch. **46**:52–63. 1908.

VON SEELHORST, C., Über den Wasserverbrauch der Haferpflanze bei verschiedenen Wassergehalt und bei verschiedener Düngung des Bodens. *Ibid.* **47**:369–378. 1899.

———, Neuer Beitrag zur Frage des Einflusses des Wassergehalts des Bodens auf die Entwicklung der Pflanzen. *Ibid.* **48**:165–177. *pls. 2.* 1900.

VON SEELHORST, C., GEORGES, N., und FAHRENHOLZ, F., Einfluss des Wassergehaltes und der Düngung des Bodens auf die Produktion und die Zuzammensetzung von Futterpflanzen, italienisches Raigras u. Klee. *Ibid.* **48**:265–286. 1900.

VON SEELHORST, C., und GEORGES, N., Der Einfluss der Düngung und des Wassergehaltes des Bodens auf den Bau und auf die Zuzammensetzung der Gerstenpflanze resp. des Gerstenkornes. *Ibid.* **48**:325–347. 1900.

VON SEELHORST, C., und FRECKMANN, W., Der Einfluss des Wassergehaltes des Bodens auf die Ernten und die Ausbildung verschiedener Getreide-Varietäten. *Ibid.* **51**:253–269. 1903.

VON SEELHORST, C., Die Bedeutung des Wassers im Leben der Kulturpflanzen. *Ibid.* **59**:259–291. 1911.

Conclusions

Under the climatic conditions of Western Cuba the transpiration of tobacco plants grown in the open ground is nearly 30 per cent greater than the transpiration of plants grown under the cheese-cloth shade commonly used for shading tobacco in that region (fig. 1). The transpiration per unit area of leaf surface is nearly twice as great in the sun plants as in the shade plants.

The shading of tobacco plants by this grade of cheese-cloth does not seem to result in a diminished production of total plant substance by the shaded plants as compared with other like plants not shaded. Since, however, the leaves of the shade-grown plants have a much greater total area than those of plants grown in the open, it is evident that the quantity of plant material elaborated per unit of leaf area is greater in the plants grown in the open.

Although the total production of dry plant substance is not influenced in any marked degree by the cheese-cloth shade, the distribution of this substance is affected in such a manner that in the shade-grown plants relatively less material is deposited in the leaves and more in the stems than in the corresponding organs of the plants grown in full light. No evident influence is exerted on the deposition of material in the roots.

BUREAU OF PLANT INDUSTRY
WASHINGTON, D.C.

A PRELIMINARY INQUIRY INTO THE SIGNIFICANCE OF TRACHEID-CALIBER IN CONIFERAE

PERCY GROOM

In connection with an investigation of the structure of the secondary wood of Indian species of *Pinus*, conducted by W. RUSHTON and myself (**2**), it seemed to me that some points of interest might be revealed by an inquiry into the relation between habitat and systematic affinity on the one hand, and, on the other, width of tracheid as measured in the spring zone. Fortunately, a comprehensive list of measurements of the diameters of such tracheids in American Coniferae is given by PENHALLOW (**4**). These, together with the measurements made by RUSHTON on Indian pines, serve as the basis for the succeeding discussion.

In framing conclusions regarding the significance of the statistics, there are a number of points of difficulty that can be removed only by further research or by information supplied by American botanists and foresters. And it is partly in the hope of exciting such research that this tentative inquiry is published. The difficulties are:

1. The caliber of the spring tracheids of a species varies in the same annual ring with height above the ground, and in different annual rings at the same level.

2. The caliber of the spring tracheids also varies in one and the same species according to the habitat in which the individual tree grows. A number of American species of *Pinus* and other conifers show considerable diversity in the habitat (edaphic and climatic) of the one and the same species.

Possibly one of the two causes above mentioned accounts for the discrepancy between PENHALLOW's measurements and mine in connection with *Pinus glabra*.

3. Information as to the exact climate (rainfall and atmospheric humidity) of various habitats of species is lacking.

4. Information as to the exact edaphic conditions, and particularly as regards amount of moisture and level of the water-table,

are likewise wanting. To select one example. By several botanists *Pinus Jeffreyi* is described as growing on "dry" or "very dry" gravelly slopes. This statement aroused my doubt because the caliber of the tracheids, according to my hypothesis, seemed to speak in an opposite sense. On referring to H. MAYR's (3) work I found that he states that this gravel must contain a rich supply of water, though the water must not be stagnant.

5. Information as to depth of root is wanting. The lack of this information is especially significant in relation to American species of *Pinus*, which show so strong a tendency for growth on sandy soil. A species described as growing on dry sand may, by virtue of its long roots or a high water-table, be growing in wet sand.

6. Other features besides width of spring tracheid may affect the supply or expenditure of water, as thickness of sap wood, percentage of spring wood, size and structure of leaf, and aggregate surface (including duration) of the leaves of the species.

Despite the possibilities of disturbance by these factors, the evidence clearly points to the view that caliber of spring tracheids of different species varies directly with climatic or available edaphic humidity, and inversely as the conditions tending to induce desiccation. It also varies with the systematic position of the genus or species.

As I was working especially at the structure of the wood of *Pinus* and as this genus offers the largest number of species and the widest range of habitats of any American coniferous genus, the first inquiry concerns it.

Pinus

For the purpose of this discussion, the genus *Pinus* will be divided into two sections. Section I includes the species whose leaves are haploxylic, whose dwarf shoots have a more or less deciduous sheath, and whose wood has non-denticulate ray tracheids and bordered pits on the tangential walls of the outer summer tracheids. Section II includes diploxylic species with a persistent sheath, denticulate ray tracheids, and no universal tangential pitting in the outer summer tracheids. In the succeeding tables the mean diameter of the spring tracheid is the mean between the radial and tangential diameters.

Considering section I of *Pinus*, it is evident that the first six species, characterized by the narrowest spring tracheids, all occupy sites that are both edaphically dry and climatically dry for long

TABLE I

PINUS, SECTION I

	MEAN DIAMETER OF SPRING TRACHEIDS IN μ		HABITAT*
	Atlantic	Pacific or North Mexican	
P. cembroides	.....	24.0	Dry ridges, dry gravel, Arizona, Mexico, at 3500 ft.
P. edulis	.....	24.5	Dry mesas, slopes, dry gravel, Colorado, Texas, New Mexico, up to 9000 ft.
P. Parryana	.....	32.0	Arid mesas and desert slopes; subtropical in California and Lower California.
P. monophylla	.....	33.0	Dry gravelly slopes, Utah to California, Arizona, at 3000–6000 ft.
P. Balfouriana	.....	32.0	Often alpine, 5000–11,000 ft.; dry or rocky ridges and slopes in California.
P. aristata	.....	33.5	Often alpine, up to 12,000 ft.; dry gravelly ridges in California, Nevada, Arizona, and Colorado.
P. albicaulis	.....	35.0	Alpine; 53° N. to British Columbia to southern California, where it reaches 10,000 ft.
P. flexilis	.....	39.0	Sandy-gravelly, sunny places, from British Columbia down to Texas, Arizona, S.E. California; attaining an altitude of 12,000 ft. in Montana; alpine also in Colorado.
P. reflexa	.....	39.5	Cool moist ravines at 6000–8000 ft. in New Mexico and Arizona.
P. Strobus	41.5	.....	Widespread in Canada and particularly the northeast of the United States; in the north on moist sandy or even swampy soil, but in the southern part of its area also on dry gravel.
P. monticola	.....	43.0	British Columbia, southward to California, etc., 2000–10,000 ft.; in cultivation prefers airy, open, rather moist situations.
P. Lambertiana	.....	45.0	Cascade and Coast Ranges in Oregon, southward along the coast to southern California, in rather moist soil with moist air.

*For particulars as to the habitats of the American Coniferae mentioned in this paper, I rely mainly upon the cited works of H. MAYR and C. S. SARGENT.

periods; two of them are also alpine species. The seventh species, *P. albicaulis*, also is alpine, but at least in the north is in a moister climate than are the preceding six, and there is no record that it is on a very pervious soil. The eighth, *P. flexilis*, is less alpine than

P. albicaulis. The ninth, *P. reflexa*, though in the climatically dry region, occupies moist sheltered spots. The remaining three species are in climatically moister regions, and one of them rather belongs to the Atlantic forest flora. The evidence, therefore, favors the view that narrowness of the spring tracheids is linked with special need for economizing water, and is thus encountered in xerophilous species.

But another interpretation is possible. The first six species, having the narrowest tracheids, all show wood of characteristic structure, differing from that of the others in that their ray parenchyma has "piceoid" pitting, and this conforms with characteristic cone structure, which agrees with that of diploxylic species. Thus these species belong to the peculiar subsection PARA-CEMBRA. Again, the first four of the species belong to one group of this subsection, namely PARRYA, while the remaining two belong to the other group BALFOURIA.

The remaining species differ from the first six in structure of medullary rays and of cone (whose scales have a terminal umbo), so that they are members of the subsection CEMBRA. And of them the first two species, with narrowest spring tracheids, belong to the subdivision of CEMBRA known as the group EU-CEMBRA; while the last four, with widest spring tracheids, are included in the other subdivision STROBUS.

Thus, in the whole series of species belonging to section I, diameter of spring tracheid is rigidly linked with systematic position. It is conceivable, therefore, on the one hand, that width of spring tracheid is a systematic or purely morphological character, not an epharmonic one; or, on the other hand, that these groups and subsections are not natural monophyletic groups, but are polyphyletic collections of types whose likenesses are determined by ecological factors. Yet, on the whole, it seems simplest to suppose that the evolution of section I of *Pinus* has been determined by available water supply, and that group PARRYA and group STROBUS represent extreme types, the former the most xerophilous and the latter the most hygrophilous.

The suggestions above given harmonize with the facts relating to East Indian pines. *P. Gerardiana*, belonging to the group PARRYA

of the subsection PARA-CEMBRA, is xerophilous, has narrower spring tracheids than any other East Indian species, the width agrees sufficiently with those of American species, as it is 31.5 μ; that is, it would occupy, from the same point of view, a middle position if ranged among the American species of PARRYA. The other East Indian pine, *P. excelsa*, belonging to section I, is a member of the group STROBUS. Its habitat is not xerophilous, and its spring tracheids are 38.5 μ in diameter (compared with 41.5 μ of *P. Strobus*).

As table II shows, section II of *Pinus* displays no such simple systematic or ecological relations as does section I. This may be due partly to the difficulties mentioned before in appraising the habit and habitat of each species, and in part to defective classification of this large section.

The first three species in table II, having the narrowest spring tracheids (29.5–33 μ), are clearly xerophilous in habitat. One of the two Pacific types, *P. ponderosa* (29.5 μ), is, according to MAYR, the first pine encountered in going west from the prairies. A little farther west, while the narrower (moister) valleys include the moisture-loving Douglas fir and *P. monticola* (43 μ), the broader (drier) valleys are occupied by prairie or by *P. ponderosa*. Still farther west, on sandy soil, Douglas fir vanishes and *P. ponderosa* is accompanied by *P. Murrayana* (34 μ), which also has narrow spring tracheids. Again, according to MAYR, in a more northern Pacific region, where during the vegetative season the prevailing relative atmospheric humidity is 80–63 per cent, Douglas fir exists; but when the humidity sinks to 54 per cent, Douglas fir is replaced by *P. ponderosa*. MAYR ranges Pacific pines found growing in warm temperate regions as follows, according to their demands for moisture, beginning with those demanding most moisture:

Soil moisture: *P. Jeffreyi* (47 μ), *P. Lambertiana* (45 μ), *P. ponderosa* (29.5 μ), *P. Coulteri* (39.5 μ).

Atmospheric moisture: *P. Lambertiana* (45 μ), *P. Jeffreyi* (47 μ), *P. Coulteri* (39.5 μ), *P. ponderosa* (29.5 μ).

Thus, in these pines which replace one another from site to site, the two with widest spring tracheids demand more moisture than the other two. It is worthy of note that the moisture-loving haploxylic *P. Lambertiana* has narrower spring tracheids than the

TABLE II

PINUS, SECTION II

Letters indicating general distribution are as follows: A, Atlantic; P, Pacific; M, North Mexican.

	MEAN DIAMETER OF SPRING TRACHEIDS			DISTRIBUTION, SOIL, ALTITUDE, ETC.
	Pseudo-strobus	Taeda	Pinaster	
1. P. ponderosa	.....	29.5(P)	.....	Dry rocky ridges, dry valleys, rarely in cold swamps; warm temperate; British Columbia to North Mexico (see subsequent comments).
2. P. tuberculata	.....	30(P)	.....	Dry sandy-gravelly slopes and ridges of Sierra Nevada and Coast Mts. from Oregon to California, 2500–5000 ft.; nearly subtropical.
3. P. rigida	.....	33(A)	.....	Dry gravelly uplands, sandy plains, cold deep swamps; Canada to N. Georgia; warm temperate; sometimes with *P. echinata*.
4. P. Murrayana	.....	.....	34(P)	Alaska to S. California and Arizona; on Sierra Nevada at 8000–9000 ft.; often on dry gravel; cool temperate.
5. P. muricata	.....	.....	35.5(P)	Cold peat bogs, barren sandy gravel, sea slopes of Coast Mts. of S. California; subtropical.
6. P. inops	.....	.....	36(A)	Sandy barren soil, dry heights; New York to South Carolina and Indiana; can be grown on the worst types of dry soil (dunes, etc.); warm temperate.
7. P. contorta	.....	.....	37(A)	Sphagnum bogs, sand dunes, exposed rocky sites, near the coast from Alaska to California; warm temperate.
8. P. arizonica	38(M)	.....	.....	Mountains of S. Arizona, Chihuahua, and Sonora; 6000–8000 ft.; warm temperate.
9. P. chihuahuana	.....	38.5(M)	.....	Mountains of New Mexico, Arizona, Chihuahua, and Sonora; 6000–7000 ft.; warm temperate to subtropical.
10. P. Torreyana	38.5(P)	.....	.....	On sand or sandy loam on the coast of California, where it is exposed to the wind, which often causes it to assume a partly prostrate habit; subtropical.
11. P. pungens	.....	.....	39(A)	Dry gravelly slopes of the Alleghany Mts. up to 3000 ft.; warm temperate.

TABLE II—*Continued*

	Mean diameter of spring tracheids			Distribution, soil, altitude, etc.
	Pseudo-strobus	Taeda	Pinaster	
12. P. Coulteri	.....	39.5(P)	.....	Warm dry slopes on the coast ranges of California; 3000–6000 ft.; warm temperate (see subsequent comments).
13. P. sabiniana	.....	39.5(P)	.....	Dry foothills of W. California, among evergreen oaks; subtropical.
14. P. insignis	.....	40(P)	.....	Sandy soil on coast of California; subtropical (see subsequent comments).
15. P. Banksiana	.....	.....	43(A)	Sandy soil to loam, capable of growing on very dry barren soil or even in peat bogs; Canada to Minnesota, etc.; cool temperate.
16. P. resinosa	.....	.....	44(A)	Sandy soil, usually in less dry soil than *P. Banksiana;* widespread in Canada and N.E. United States; warm temperate.
17. P. glabra*	.....	.....	(44) 37(A)	Moist sand or rather moist forest soil; South Carolina to Florida; subtropical.
18. P. cubensis	.....	44(A)	.....	Subtropical and tropical, on land just above flood area; South Carolina, Florida, West Indies, etc.
19. P. serotina	.....	47(A)	.....	"The pond pine," at margin of swamps in wetter soil than *P. cubensis;* N. Carolina to Florida; subtropical.
20. P. Jeffreyi	.....	47(P)	.....	Moist sandy gravel on mountains in California; 6000–8000 ft.; warm temperate (see subsequent comments).
21. P. clausa	.....	.....	48(A)	Barren stretches of sand on higher ground than *P. cubensis;* Alabama to Florida, coast of Gulf of Mexico; subtropical.
22. P. echinata	.....	.....	48(A)	New York to Florida, Louisiana, and Texas; subtropical.
23. P. palustris	.....	49(A)	.....	Sand, often coarse, rarely low wet soil, never in swamps; along the coast from S.E. Virginia along the Gulf of Mexico to Mississippi.
24. P. Taeda	.....	49.5(A)	.....	Low wet clay or sand, less dry and more loamy soil than *P. palustris;* S. Delaware to Florida, Texas, Arkansas, etc.
25. P. tropicalis†	.....	50.8(A)	50.8(A)	Tropical; Cuba, Isle of Pines.

*44 is my own measurement; 37 that recorded by PENHALLOW.

† As to the synonymy, and consequently the section to which this pine belongs, I am not informed.

diploxylic *P. Jeffreyi* of apparently similar moisture-demanding habits. The other two with narrowest tracheids are both obviously xerophilous as regards edaphic conditions, and one of them is also climatically so in so far as it is a Pacific species.

As a second group of species may be taken those with narrow spring tracheids, between 34 and 37 μ in diameter. All these occupy physically or physiologically dry soils, or where the evidence of this is least obvious, as in *P. Murrayana*, the species often accompanies *P. ponderosa*. Although *P. inops* (36 μ) occasionally is distributed together with two species belonging to the moist subtropical Atlantic region, namely *P. echinata* (48 μ) and *P. Taeda* (49.5 μ), it is in areas less moist than that region, where *P. rigida* (33 μ) is also encountered.

The next two species, *P. arizonica* (38 μ) and *P. chihuahuana* (38.5 μ), mingling on the mountains of dry Mexico, agree closely in diameter of spring tracheids, although the two species belong to different systematic subdivision of section II of *Pinus*. Closely agreeing with them is *P. pungens* (38.5 μ), which belongs to the same systematic group as *P. arizonica* and is xerophilous in distribution on the Pacific Coast.

The fourth group containing four species, with width of spring tracheids between 39 and 40 μ, includes one Atlantic species growing in very pervious soil (gravel) and three Pacific species growing on soils that we may presume are not pervious gravels, for *P. Coulteri* grows on gravelly loam and *P. insignis* occupies sand and is used to fix sand dunes, being apparently uninjured by the salt water flung over its roots by spring tides (MAYR). Comparison between *P. Coulteri* and *P. ponderosa*, which endures greater drought, has been made above.

The next two species, with the width of spring tracheids between 43 and 44 μ, differ from all those previously discussed in being largely cool temperate in distribution; they are northern forms. So far as supply of moisture is concerned, it is difficult to see why the cool temperate *P. Banksiana* (43 μ) should have relatively wide tracheids, as it can grow well on dry barren sand or in peat bogs; and even *P. resinosa* (44 μ) for a time can endure dry sand. It may be that, just as with a higher temperature of climate, trees

require a higher rainfall, so if narrowness of spring tracheids be a form of protection against desiccation, cold temperate pines might be able to afford to have wider tracheids than warm temperate growing in equally dry situations. *P. Banksiana* (43 μ) has narrower tracheids than *P. resinosa* (44 μ), which usually grows in less dry places. These two species are accompanied often by the haploxylic moisture-loving *P. Strobus* (41.5 μ), whose spring tracheids are narrower, just as is the case with the haploxylic *P. Lambertiana* compared with its diploxylic occasional companion, *P. Jeffreyi*.

The remaining species, excepting *P. Jeffreyi*, are subtropical Atlantic, occurring near the coast in a region where there is a heavy rainfall during summer and winter, and the air is moist. It is significant that in this group of pines possessing the widest spring tracheids, these latter agree sufficiently in diameter whether the species belong to the section TAEDA or to PINASTER. First, there are two, one belonging to each section, with a diameter of 44 μ; then there are four belonging to TAEDA, two with the diameter 47 μ, and two with 49 μ and 49.5 μ, respectively. Lastly, there are two belonging to PINASTER, with the diameter of 48 μ. The species that is the most clearly tropical in distribution is the one having the widest spring tracheids; and such is likewise the case in India where the tropical *P. Merkusii* grows on sites receiving, at least periodically, very considerable supplies of moisture.

If again we range the species in accordance with MAYR'S grouping as subtropical, warm temperate, cool temperate, and alpine, in order so far as possible to determine temperature as a factor, the following facts come out.

Subtropical.—The five diploxylic species (nos. 2, 5, 10, 13, 14 in table II), characterized by narrow spring tracheids ranging from 30 to 40 μ, are all Pacific species, with or without marked perviousness of soil. The remaining diploxylic species (nos. 17, 18, 19, 21, 23, 24, 25), having wider spring tracheids, are Atlantic species living in a moist climate. The Pacific and Atlantic groups both include representatives of the sections TAEDA and PINASTER.

Warm temperate.—The first six diploxylic species, with the narrowest spring tracheids ranging from 29.5 to 38.5 μ, include two

Pacific species (nos. 1 and 7) and two Atlantic species (nos. 3 and 6), all four of xerophilous habitat; also two Mexican species (nos. 8 and 9) growing in a dry climate and at least sometimes on dry soil. The three species with widest spring tracheids include two Pacific species (nos. 16 and 20), definitely showing larger demands for moisture of soil and air than the other Pacific warm temperate species, and one Atlantic species (*P. resinosa*) that is not edaphically xerophilous as are the other Atlantic species in this warm temperate group. There is not the sharp contrast between the Pacific and Atlantic species that there is in the subtropical group, possibly because the Pacific species are not at so great a disadvantage as regards supplies of moisture, either because they belong to the northern Pacific, which is characteristically moister than the southern (no. 1 partly, and no. 7), or because they grow on mountains where the climate is moist (nos. 12 and 20), while the Atlantic species with warm tracheids are definitely in dry soils.

Cool temperate and alpine species.—Of the two diploxylic species ranged under this heading, *P. Murrayana*, the Pacific species often on dry ground and reaching alpine situations, has narrower spring tracheids (34 μ) than has the other, *P. Banksiana* (43 μ), though this latter can grow on very dry soils.

Summary.—The American species of *Pinus* having the narrowest spring tracheids are all more or less markedly xerophilous in distribution; those with the widest spring tracheids are all subtropical and more or less hygrophilous in distribution. The few East Indian species show similar characters in this respect. In section I of *Pinus*, so far as the measured American and East Indian species are concerned, differences in tracheid width run parallel with distinction in systematic affinity, thus suggesting that the evolution of the different groups of this section has been determined by the available water supply.

Other North American Coniferae

The succeeding table records the width of the spring tracheids as given by PENHALLOW, and the distribution of other American conifers.

Table III shows that evidence in favor of the view that scantiness and abundance of available water supply are respectively

TABLE III

	Width of spring tracheids in μ			Distribution, soil, altitude, etc.
	Atlantic	North Mexican	Pacific	
Torreya—				
T. californica	.....	.....	38	California, 3000–5000 ft., moist soil near streams; subtropical.
T. taxifolia	40	.....	.....	W. Florida, moist soil; moderately warm.
Sequoia—				
S. gigantea	.....	.....	39	Warm temperate.
S. sempervirens	.....	.....	55	Very moist soil and moist air; subtropical.
Chamaecyparis—				
C. Lawsoniana	.....	.....	18	S.W. Oregon and California, moist soil; warm temperate.
C. nutkaensis	.....	.....	25.5	Alaska to British Columbia, Cascade Mts.; adapted to the moistest air and a larger rainfall than *C. Lawsoniana;* warm to cool temperate.
C. thyoides	32	.....	.....	Maine to N. Florida; cold swamps.
Cupressus—				
C. arizonica	.....	25	.....	Arizona, Sonora, Chihuahua, 3000–5000 ft.
C. Macnabiana	.....	.....	30	California, dry hills and low slopes; subtropical.
C. Goveniana	.....	.....	32	California coast up to 3000 ft., hot rocky slopes, often on banks of streams; tropical.
C. macrocarpa	.....	.....	39	California, south of Monterey Bay, exposed constantly to the sea breezes; subtropical.
Juniperus—				
J. sabinoides	.....	17	.....	Texas to Mexico; up to the limits of vegetation on high mountains in Central Mexico.
J. nana	18	.....	.....	Labrador to New York and Utah.
J. californica	.....	.....	18	Sacramento River to Lower California; dry mountain slopes, desert slopes of Tehachapi Mts.; subtropical.
J. occidentalis	.....	.....	18	6000–10,000 ft., dry rocky ridges of Blue Mts., where it is a shrub on dry hot ridges; cool temperate.
J. monosperma	.....	19	.....	Rocky Mts. to Arizona and Mexico, 3500–7000 ft., gravelly slopes.
J. communis	.....	.....	20.5	Greenland to mountains of California and Arizona.
J. pachyphlaea	.....	21	.....	S.W. Texas to desert ranges of Arizona, 4000–6000 ft., arid mountain slopes; subtropical.
J. Sabina	21.5	.....	.....	Nova Scotia to Rocky Mts. and Montana; slopes and river banks.

TABLE III—*Continued*

	Width of spring tracheids in μ			Distribution, soil, altitude, etc.
	Atlantic	North Mexican	Pacific	
Juniperus (*cont.*)—				
J. utahensis	.....	23	.....	Rocky Mts. to Sierra Nevada, up to 8000 ft., arid hills and slopes.
J. virginiana	32	.....	32	New Brunswick to Florida and tropical forests; Atlantic Coast to the prairies (100° W.) north of 54° N.; snowy summits of Rocky Mts., sea coast of British Columbia; rocky, dry, gravelly soil, sterile sand, meadow, moist, or swampy soil; cold to tropical.
Larix—				
L. americana	39.5	.....	.....	Arctic to West Virginia; in the north on well drained uplands, in the south in cold deep swamps; cool temperate.
L. occidentalis	.....	.....	42	British Columbia to Oregon, Montana, and Idaho, 2000–7000 ft.; moist bottom lands and dry mountain slopes; cool temperate.
L. Lyallii	.....	.....	43	Alberta and British Columbia, 7000–8000 ft. near timber line; "alpine."
Picea—				
P. rubra	29.5	.....	.....	Prince Edward Island to N. Carolina; well drained uplands and mountain slopes.
P. Breweriana	.....	.....	33	California and Oregon, 4000–7000 ft.; mountain peaks and ridges, near the timber line; "alpine."
P. alba	33.5	.....	.....	Labrador to New York to Montana; in the southern regions it is a low tree in swamps; it extends far north into permanently icy ground; cool temperate.
P. sitchensis	.....	.....	34	Alaska to California; moist sand or swamp, or wet rocky slopes in the north; solely coastal (within 50 miles of coast); more sensitive to dryness than to cold.
P. nigra	34.5	.....	.....	Alaska to Labrador to Virginia; in the north in well drained bottom lands; in the south in swamps and sphagnum bogs.
P. Engelmanni	.....	.....	35	British Columbia (5000 ft.), Arizona (11,500 ft.), high mountain slopes, well developed in moist canyons, very high up becomes shrubby; cool temperate.
P. pungens	.....	.....	38	Wyoming to Colorado and Utah, 6500–10,000 ft.; banks of streams, moist valleys; cool temperate.

TABLE III—*Continued*

	Width of spring tracheids in μ			Distribution, soil, altitude, etc.
	Atlantic	North Mexican	Pacific	
Abies—				
A. Fraseri	30.5	.....	.....	S.W. Virginia to Tennessee, 4000–6000 ft., on moist slopes.
A. lasiocarpa	.....	.....	33.5	Alaska to Arizona; 4000 ft. in British Columbia; 12,000 ft. in Colorado; "alpine."
A. magnifica	.....	.....	38.5	S. Oregon, 5000–7000 ft.; Sierra Nevada 6000–10,000 ft.; cool temperate.
A. concolor	.....	.....	39	S. Colorado to California and arid regions of New Mexico and Arizona; "moist canyons" of Californian Sierras; warm cool temperate.
A. amabilis	.....	.....	40	British Columbia to Oregon, high mountain slopes, often with *A. nobilis;* cool temperate.
A. balsamea	40	.....	.....	Labrador to mountains of S.W. Virginia; often in low swampy ground or on well drained soil, often with *Picea alba;* cool temperate.
A. nobilis	.....	.....	41	Cascade Mts., Washington to California, 2500–5000 ft., often with *A. amabilis;* warm to cool temperate.
A. bracteata	.....	.....	41.5	California, 3000–6000 ft., moist cool soil.
A. grandis	.....	.....	49.5	Vancouver to California, Idaho, Oregon, Montana; near the coast on moist ground; in the interior on moist slopes; 2500–7000 ft.; warm temperate.

associated with narrowness and wideness of spring tracheids in the different species or genera is provided by *Torreya*, *Chamaecyparis*, *Sequoia*, and *Juniperus;* somewhat favoring the view are *Cupressus* and *Picea;* indifferent in indication from this standpoint are *Abies* and *Larix*.

The enumerated species of *Juniperus* all seem to be actually or potentially xerophilous in habitat, and, with one exception, have very narrow spring tracheids (17–23 μ). The one exception is *J. virginiana*, which has rather narrow spring tracheids, and a remarkable range of distribution as regards climate and soil (it is possible that the specimen of wood measured was derived from a tree growing in a moist site).

Contrasting with *Juniperus* is *Torreya*, in which both species

inhabit moist places and have relatively wide spring tracheids, 38 μ in the Pacific species, and 40 μ in *T. taxifolia* of the moister climate of Western Florida.

Sequoia sempervirens (55 μ), which not only has larger leaves but also grows in a warmer and damper climate and moister soil than *S. gigantea* (39 μ), exceeds all other measures of North American Coniferae in width of spring tracheids.

Of the two Pacific species of *Chamaecyparis*, *C. Lawsoniana* (18 μ) has unexpectedly narrow spring tracheids, for it grows preferably on moist soil. Compared with it, *C. nutkaensis* has wider spring tracheids (25.5 μ) and grows in cooler and much moister regions, where it is limited to places having the moistest of air. Still wider spring tracheids are those of the Atlantic *C. thyoides* (32 μ), though it grows in cold swamps.

Cupressus arizonica (25 μ), living in the driest region (Mexican), is likewise the species with narrowest spring tracheids. The three other species measured are Californian, and the one with narrowest spring tracheids, *C. Macnabiana* (30 μ), appears to be the one of the least moist habitat, for *C. Goveniana* (32 μ) is said to occur often on the banks of streams, while *C. macrocarpa* (39 μ) is constantly in damp sea air. Yet this last species can be used with *Pinus insignis* to fix sand dunes, and its roots can be laved with sea water, so that without further investigation it is impossible to say that *Cupressus*, as a whole, definitely favors the view here propounded.

The American species of *Abies*, whose tracheids have been measured, neither clearly support nor oppose the view. True it is that *A. lasiocarpa* (33.5 μ), the species that is nearly alpine and is described as "alpine," has with one exception the narrowest spring tracheids, but that exception is *A. Fraseri* (30.5 μ), which grows on moist slopes in moist cool air. So far as habitat is concerned, there appears to be no reason why *A. Fraseri* (30 μ) should have much narrower tracheids than the more northern Atlantic form *A. balsamea* (40 μ), which indeed often grows in swamps, and sometimes even sphagnum swamps, unless, indeed, the cause be the same as that already suggested in connection with the parallel cases of *Pinus Banksiana* and *P. resinosa;* apparently *A. balsamea* and *P. Banksiana* are found growing together.

Of the genus *Picea*, *P. rubra* (29.5 μ) is the species having the narrowest spring tracheids. Of the next two species, *P. Breweriana* (33 μ) is the only American Pacific alpine (or subalpine) species; while *P. alba* (33.5 μ) goes very far north, where, according to MAYR, it can grow on permanently icy soil. Farther south *P. alba* often occurs in swamps, including occasionally sphagnum bogs, and frequently mingles with *P. nigra* (34.5 μ). The remaining three species, *P. sitchensis* (34 μ), *P. Engelmanni* (35 μ), and *P. pungens* (38 μ), grow in places where air and soil are moist. Thus the three species whose habitats are regularly or potentially xerophilous have the narrow spring tracheids, whereas the two species with the widest spring tracheids show clear demands for more moisture. Yet this indication is weakened by *P. rubra* and *P. sitchensis*. The three Atlantic species (29.5–34.5 μ) belong to the section MORINDA; of the four Pacific species, *P. Breweriana* (33 μ) is in section OMORICA, while the other three (34–38 μ) belong to CASICTA, and their delicate loose cone scales seem to suggest that moistness of air characterizes their habitat.

Larix shows the narrowest spring tracheids in *L. americana* (39.5 μ), which reaches arctic sites, and, when farther south (reaching Virginia), grows in cold deep swamps, and particularly occurs in sphagnum swamps. Of the other two species, *L. occidentalis* (42 μ) and *L. Lyallii* (43 μ) differ but little in width of spring tracheids, but the one with wider tracheids is that which is nearly alpine, in fact is often termed "alpine." Thus *Larix* gives no clear indication of a correlation between narrowness of tracheid and xerophily of habitat. Compared with the evergreen conifers of the same habitat, the spring tracheids of *Larix* are usually wider, as might be anticipated (1).

In connection with the question of the influence of two of the factors deciding the width of the spring tracheids, namely systematic affinity and habitat, some suggestive results are yielded by a comparison of these widths in different species occupying the same habitats.

In the northern Atlantic region, *Abies Fraseri* (30.5 μ) and *Picea nigra* (34.5 μ) often grow together, as do *Abies balsamea* (40 μ) and *Picea alba* (33.5 μ). These two species of *Picea*, only

slightly differing in tracheid width, often mingle; thus in a second manner is shown that there is some problem as to the unexpected width of spring tracheids in *Abies balsamea*. *Juniperus virginiana* (32 μ) often mingles with the two species of *Picea* in moist ground and does not differ much from them in tracheid width. But *Pinus Strobus* (41.5 μ), often replacing these three species, and *Pinus Banksiana* (43 μ), often occurring with *Picea alba*, though agreeing fairly with one another, have much wider tracheids than these three species. *Larix americana* (39.5 μ) often largely replaces *Abies balsamea* (40 μ) and *Picea alba* (33.5 μ) on sphagnum bogs.

On the warm temperate Pacific coast, *Pinus insignis* (40 μ) and *Cupressus macrocarpa* (39 μ) are often grown together as dune fixers, and nearly agree in tracheid width.

Still closer agreement characterizes *Abies concolor* (39 μ) and *Sequoia gigantea* (39 μ), which are often associated in the warm to cool temperate Pacific forests. Again, the equivalent species of *Pinus* have relatively wide spring tracheids, for *P. Jeffreyi* (47 μ) often is associated with *Abies concolor* (39 μ), whose demands for moisture are about equal to those of *P. Lambertiana* (45 μ) (MAYR).

In the cool temperate Pacific region, the deciduous *Larix occidentalis* (42 μ) has much wider spring tracheids than its frequent companion *Pinus Murrayana* (34 μ); while *Abies nobilis* (41 μ) and *Abies amabilis* (40 μ), which occur together, differ only slightly in width of spring tracheids.

In the Pacific so-called alpine region, there is a remarkable approximate agreement in the width of spring tracheids in three genera: *Abies lasiocarpa* (33.5 μ), *Picea Breweriana* (33 μ), *Pinus Balfouriana* (32 μ), *Pinus aristata* (33.5 μ), and *Pinus albicaulis* (35 μ). All these contrast with the alpine larch, *Larix Lyallii* (43 μ), whose wide tracheids correspond with the deciduous habit.

American deciduous species of Quercus

In a previous paper (1) I have shown that the width of the spring vessels in *Quercus* is decided partly by the habit of the species, and that these vessels are wider in deciduous than in evergreen species, even though the latter may grow in moist Florida, as is the case with *Q. virginiana*. The subjoined statistics suggest strongly

TABLE IV

AMERICAN DECIDUOUS SPECIES OF QUERCUS

W, white oaks; B, black oaks; all are warm temperate excepting *Q. lobata*, which is subtropical.

	WIDTH OF WIDEST SPRING VESSELS				HABITAT
	Atlantic		Pacific		
	W	B	W	B	
Q. Garryana	.....	.....	0.338	.....	Dry habitat; Vancouver to California and Oregon; dry gravelly slopes of low hills; also between prairie and pine forests.
Q. lobata	.....	.....	0.356	.....	Subtropical (in the same region as the evergreen *Q. chrysolepis*, *Q. Wislizeni*, and *Q. agrifolia*) in California; often after losing its leaves in dry autumn, acquires fresh ones after rain in November, hence tending to be sub-evergreen.
Q. obtusiloba	0.362	.....	.....	.....	Dry sandy gravel, or on hard impervious loam where dryness and moistness alternate suddenly; Cape Cod to Florida, Mississippi, Texas, etc.
Q. macrocarpa	0.372	.....	.....	.....	Variable as regards soil, but showing power of enduring some degree of dryness by growing on higher sites at the edge of prairie or on dry hills in northwest region of its area, which is wide, extending from Nova Scotia and Ontario to Minnesota, Texas, etc.
Q. Macdonaldi	.....	.....	0.372	.....	Islands off California.
Q. californica	.....	.....	.....	0.378	W. Oregon, coast ranges of California, 7000–8000 ft. in western slopes of Cascade Mts., to mountains of S. California (optimum 6000 ft.).
Q. Prinus	0.387	.....	.....	.....	Various habitats; Ontario to Alabama, Tennessee, etc.
Q. rubra	.....	0.387	.....	.....	No special soil; goes farther north than any other American oak, and on Alleghany Mts. ascends into the fir region.
Q. coccinea	.....	0.412	.....	.....	Usually light sand, but also dry gravelly uplands and prairies; Ontario to Alleghany Mts., and North Carolina to Nebraska, etc.
Q. tinctoria	.....	0.412	.....	.....	Dry gravelly uplands and ridges; Ontario to Minnesota, Florida, Mississippi, Texas, etc.
Q. palustris	.....	0.419	.....	.....	Good wet soil (not swamp) at the edges of swamps and margins of rivers; Canada to Missouri, Virginia, Arkansas, etc.

TABLE IV—*Continued*

	Width of widest spring vessels				Habitat
	Atlantic		Pacific		
	W	B	W	B	
Q. aquatica	.....	0.438	.....	.....	Sandy borders of swamps; Delaware to Florida, Gulf States, Texas, Oklahoma, etc.
Q. Muhlenbergii	0.444	.....	.....	.....	Variable habitat; dry hills to deep rich bottom lands and rocky banks of streams; Ontario to Columbia, N. Louisiana, Texas, etc.
Q. alba	0.45	.....	.....	.....	Optimum soil is fresh (rather moist) loam in undulating country or on the banks of streams; but the habitat varies from sandy plains to gravelly ridges; Ontario to N. Florida, Minnesota, Texas, etc.
Q. bicolor	0.45	.....	.....	.....	Borders of streams and swamps; Ontario to N. Georgia and W. Missouri; does not extend so far south as *Q. alba*.
Q. Michauxii	0.587	.....	.....	.....	Borders of swamps and streams; Delaware to Florida, Gulf States, Kentucky, etc.

that in the deciduous species width of spring vessel is at least largely determined by systematic affinity and by available water supply; the spring vessels being narrower in species belonging to physically or physiologically drier places, and for the same type of habitat being narrower in black oaks than in white oaks.

The points of significance in connection with the deciduous oaks are:

1. Of the six species with narrowest spring vessels (0.338–0.378 μ), four are Pacific species and characterized by drier climate than the Atlantic species. Among the four Pacific species, the one with the narrowest vessels is the one whose soil is definitely stated to be dry gravel. The second is subtropical in the region of evergreen species, and itself approaches the evergreen stage. Of the other two, one has a maritime climate, and the other no dryness of habitat (apart from the Pacific climate). Of the two Atlantic species, one occupies an edaphically dry habitat, while the other, though variable as regards habitat, shows a power of living on at least rather dry sites.

2. Considering the Atlantic species, and taking separately the two series representing respectively the white oaks and black oaks, the former of these begins with the two species just referred to, continues with two species of variable habitat as regards soil, passes to one in which the optimum soil is rather moist but varies, and concludes with two species confined to thoroughly moist soil. The last of these also occurs in the region where the American pines exhibit the greatest caliber of tracheids, namely, Florida and the Gulf States.

The series of Atlantic black oaks commences with wider vessels than the series of white oaks. The first species shows no special choice of soil, but can grow farther north than any other American warm temperate species; the next two species clearly show preference for dry situations, or at least a capacity for thriving on dry gravels; the series, like that of the Atlantic white oaks, concludes with two species confined to thoroughly moist soil on the borders of swamps and rivers.

Summary

1. There is considerable evidence that the width of the spring tracheids in evergreen Coniferae is largely decided by two factors, systematic affinity and available water supply. So far as the latter is concerned, the spring tracheids are generally narrowest in species of xerophilous habitat.

2. In American species of *Pinus* belonging to section I (Haploxylon), variation in the width of the spring tracheids runs quite parallel with difference of systematic affinity and of available water supply (including influences promoting transpiration). Thus the first step in the evolution of this section of *Pinus* would appear to have been a division into a more xerophilous type (ancestral PARACEMBRA), and a less xerophilous type (ancestral CEMBRA), and each of these subsections would appear to have undergone similar division into more or less xerophilous groups, that is, into PARRYA and BALFOURIA, also EU-CEMBRA and STROBUS. The two East Indian species, *P. Gerardiana* and *P. excelsa*, structurally accord with this theory.

3. Among American species of *Pinus* belonging to section II (Diploxylon), those with narrow spring tracheids are more xerophi-

lous in distribution, while those with the widest tracheids belong to a subtropical or tropical moist climate. Though in general this section of *Pinus* supports the theory given in paragraph 1, there are in it certain species in which width of tracheid does not appear to correspond with the supply of available water. Such discrepancies, whether real or only apparent, may be due to one or more of the intervening causes mentioned in paragraph 6.

4. Species of other North American genera of evergreen Coniferae show differences in the width of spring tracheids that may possibly be partly due to differences in affinity; as species of the same habitat, but belonging to different genera, may differ considerably in tracheid width, or, on the other hand, may approximate to agreement. Some of these genera, namely, *Torreya*, *Chamaecyparis*, *Sequoia*, and *Juniperus*, support the view that the width of the spring tracheid is correlated with available water supply; somewhat favoring the view are *Cupressus* and *Picea;* indifferent in indication are *Abies* and *Larix*.

5. The theory here propounded derives support from measurements of the width of the spring vessels of American deciduous species of *Quercus*. For narrowness and wideness of spring vessels in the main are respectively associated with scantiness and abundance of water supply. But in the same kind of habitat the deciduous black oaks would seem to have narrower spring vessels than are possessed by the deciduous white oaks.

6. Though the evidence as a whole strongly favors the theory here propounded, much fuller information is necessary before a safe conclusion may be drawn. Hence this inquiry and the suggestions here given must be regarded as tentative and issued in the hope of stimulating inquiry in regard to factors that may intervene, such for instance as the following: climate (including evaporation power), exact soil water-content, level of water-table, etc., that form the environment of the different species of conifers; also, depth of root, duration of foliage and size of aggregate leaf surface, rate of transpiration, width of sap wood, etc., in the different species; also, variations within one and the same species in regard to the features just mentioned, as well as in the width of the spring tracheids, in different habitats.

IMPERIAL COLLEGE
LONDON

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NOTE ON THE ASCOSPORIC CONDITION OF THE GENUS ASCHERSONIA MONTAGNE[1]

ROLAND THAXTER

(WITH SEVEN FIGURES)

The genus *Aschersonia* includes a group of entomogenous fungi which have hitherto found a place among the Sphaeropsideae, since, as far as I am aware, no ascosporic condition has as yet been observed in connection with any of them. Although a great majority of the forty or more species which have been described, for the most part from the tropics, are said to occur on the leaves, etc., of various hosts among the vascular plants, there can be no question in the mind of anyone who has had an opportunity to examine them in a fresh condition that they are strictly entomogenous, like the species of the genus *Hypocrella*, which have a similar habitat on various types of scale insects; and, as is well known, two species of the genus have been successfully employed in Florida against certain scales attacking *Citrus*. As in the case of other entomogenous fungi, the character of the host plant on which species of *Aschersonia* have been reported is thus a matter of very little importance, except in so far as it may suggest the nature of the scale which has been attacked while feeding on it. Although it is not improbable that some of the species are not restricted to closely similar hosts, there are indications that others are more definitely conditioned in this respect, and an examination of this matter from the entomological side is much to be desired. Unfortunately, very little information is available in this connection, and the actual hosts of the too numerous and ill defined species, a majority of which have been described within the past fifteen years, are, with a very few exceptions, quite unknown.

In view of the general characteristics of *Aschersonia*, it has been naturally assumed that the ascosporic form, if it exists, would find a place among the Hypocreaceae, the often bright though very variable and inconstant colors and comparatively soft con-

[1] Contributions from the Cryptogamic Laboratories of Harvard University, LXII.

sistency of the different species pointing to this conclusion. It has been suggested that they might be imperfect conditions of species of the ascomycetous genus *Hypocrella*, with which, owing to their similar mode of life, they are apt to be associated; and this suggestion is still further supported by the fact that when a flat hemispherical type of *Aschersonia* has become blackened by age and exposure, or colored by the sooty disintegrated material of accompanying *Capnodia*, which grow on the excreta of various hemipterous insects, it is often difficult to distinguish the two by their gross appearance. Definite information in regard to this connection, however, has hitherto been lacking, and, as already mentioned, I have found no record of observations which might throw light upon it. P. HENNINGS in the ASCHERSON *Festschrift*, where he discusses the validity of the generic name and certain other matters, states that he was informed by ZIMMERMAN, whose contributions to the knowledge of Javan entomogenous fungi are well known, that although he sought for them with care he never encountered any individuals which showed indications of an ascosporic fructification.

During the past year (1912–1913) I had an opportunity to spend some months on the islands of Grenada and Trinidad, and having the matter in mind made a special effort to discover this problematical ascosporic form. In the locality where I remained during practically my whole stay in Grenada, *Aschersoniae* were by no means numerous, and only three species were met with. These forms, moreover, were comparatively rare, although one of them, the well known and characteristic though very variable *A. turbinata*, was found several times. A few specimens of this species in the original gathering from a certain locality showed, when carefully examined, certain not very conspicuous but suspicious looking pustules, containing cavities unlike those of the pycnidia, which appeared to be young perithecia, and by a systematic search in the same spot I was able to obtain numerous specimens bearing the perfect form fully and characteristically developed. Unluckily, the majority of these specimens were accidentally destroyed by fire, together with many other mycologic treasures, but a sufficient number were saved, both dry and in alcohol.

In Trinidad, where the flora as well as the insect fauna is far more varied, *Aschersoniae* were numerous, and in most instances it was possible to gather abundant material of each species. These gatherings in the case of four or five species usually included the ascosporic condition, which was often abundant, and, as in the case of *A. turbinata*, occurred either by itself or associated on the same stroma with the pycnidial form; so that there could be no question as to the actual connection of the two conditions. As far as could be determined, the position of growth, whether on the upper or lower side of a leaf for example, in shady and moist or in drier and more open situations, has little if any influence on the development of the perfect condition. In some instances it appeared to follow the pycnidia in older specimens, while in others it was as evidently primary in its development and unaccompanied by pycnidia.

The general character and appearance of the perfect condition recall those of some species of the genus *Cordyceps*, to which *Aschersonia* is evidently closely related; and, as in this instance, the association of the perithecia and the development of perithecial stromata varies in different cases. In some instances the perithecia may be closely and definitely grouped in a compact and prominent stromatic outgrowth from the general stroma, which may be otherwise sterile, while in many the whole stromatic mass may become transformed into a pulvinate aggregation of densely crowded perithecia. The general appearance of such forms, which in one instance may be definitely stalked, is not unlike that of some species of *Cordyceps* or *Hypomyces*. In other cases the perithecia may be irregularly scattered in a somewhat looser stroma, and might at first be mistaken for the common *Cordyceps* (*Torrubiella*) *arachnophila*, which is often found on leaves with or without its imperfect or *Isaria* (*Gibellula*) condition. But in this instance, although the host may be as completely obliterated as it is by *Aschersoniae*, the perithecia are always much more prominent.

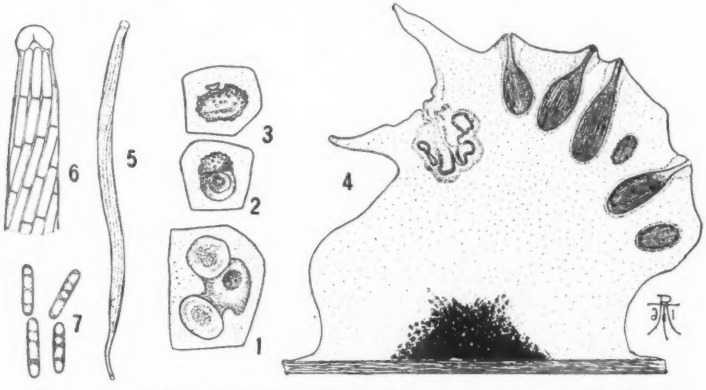
Having assembled a considerable number of *Aschersoniae* from various sources, it was first my intention to attempt a revision of the genus, but an examination of the literature and such material as is available has made it evident that this is hardly possible at

the moment, the great variability of the individual species as regards habit, size, and color, the usually insignificant differences in their spores as well as the absence of any information as to the nature of their true hosts, except in a very few cases, combining to make their systematic study a matter of great difficulty. It has seemed desirable, therefore, in the present connection to attempt no more than a brief preliminary note on the ascosporic stage of *A. turbinata*, a species which, although it is extremely variable in habit, size, and color, is in its typical form quite unmistakable.

Although the perithecial stromata of *Aschersonia turbinata* are less highly specialized than they are in some of the species, the perithecia are usually aggregated in more or less distinct pustules which, more frequently in this than in others, seem to arise after the pycnidial form has practically ceased its activities. Often, however, the whole stroma is perithecigerous, and no pycnidia precede or accompany them. In some cases these perithecial groups are very small, as in fig. 1, where less than a dozen have been produced from an old stroma bearing two well developed pycnidial cups. In fig. 2 a smaller but similar cup is associated with a much more definitely developed perithecial pustule, and fig. 4 shows in section a similar condition. In fig. 3 almost all of the original stroma is perithecigerous, a small pycnidial cup being present at the side, while the perithecia are more scattered. The section of such a specimen (fig. 4) shows a continuous homogeneous stroma, composed in all parts of absolutely identical, closely and intricately interwoven, thick-walled, undifferentiated hyphae; so that, were it not otherwise evident, there can be no question that the perithecia observed are those of the *Aschersonia*, and not of some other fungus parasitic on its stroma. It may here be mentioned, however, that several such parasites have been observed, although their characteristics are quite different.

The perithecial cavities, as shown in fig. 4 at right, are almost completely imbedded in this stroma. They are bottle-shaped, with a relatively narrow and well defined neck, about $440 \times 150\ \mu$, and are surrounded by a more dense, thin perithecial wall, the substance of which is like the similar but broader layer which sur-

rounds the neck and forms the bulk of a definite though not very prominent papilla which marks the position of the perithecium externally, and is perforated by the ostiole. The asci (fig. 5), which arise from a slight cushion at the base of the perithecial cavity, are about 210×7–8 μ, rather slender at maturity, tapering slightly to the peculiarly differentiated apex, which is modified (fig. 6) in a fashion exactly resembling that seen in the asci of *Cordyceps* and its allies. As the asci mature, the stalk becomes more elongate and slender than is represented in fig. 5, and the



FIGS. 1–7.—*Aschersonia turbinata* Berk.: figs. 1–3, three stromata bearing pycnidial cups and perithecial pustules, ×3.5; fig. 4, section of a stroma similar to that shown in fig. 2; a pycnidial cup at the left, the perithecial pustule at the right (the remains of the coccus host in the middle next the substratum (Zeiss A+2); fig. 5, ascus not fully mature (Zeiss D+4); fig. 6, tip of a nearly mature ascus showing segmented spores, and fig. 7, separated spore-segments; both Leitz water im.+12; figs. 4–7 are reduced to one-half.

eight filamentous spores, which are at first cylindrical and continuous, are later divided by septa as in *Cordyceps*. The segments thus formed eventually separating from one another, the ascus becomes filled with countless spores, rodlike in form, about 10–12 ×2–2.5 μ, with rounded ends (fig. 7). The spores and their segments are conspicuously vacuolate, so that they present a banded appearance which gives them a distinct individuality.

The characters briefly enumerated above apply in general to the perfect conditions of the remaining species in which they have

been observed, the specific variations, in so far as I have examined them, consisting in minor differences relating to the distribution, form, and size of the perithecia, the size of the spore-segments, etc., but since, for the reasons above stated, it seems almost impossible at the moment to determine them accurately, any further account of them must be deferred.

HARVARD UNIVERSITY

MORPHOLOGICAL INSTABILITY, ESPECIALLY IN PINUS RADIATA

FRANCIS E. LLOYD

(WITH TWO FIGURES AND PLATE XIV)

The various behaviors of the vegetative and reproductive shoots in the Coniferae have for many years been the objects of extended observation and experiment, and these have been the basis of a massive literature. From this we may derive no mean conception of the amount of morphological instability which characterizes that genus which, in some regards at least, is the most highly specialized of all, namely *Pinus*. Of the conditions which discover such instability, injury has been the most efficient, the resulting unusual developments being said to be due to disturbed nutrition, especially over-nutrition. Precisely what is meant by this is not and cannot at present be stated, so that any light which experiment or the diversity of behavior in nature may afford us should be welcomed, especially if it may lead to a more specific indication of the most potent of the causes which must always be at play.

Evidence of such specific value is given us by the Monterey pine (*Pinus radiata*), a species as definitely restricted to a small area as the famous Monterey cypress (*Cupressus macrocarpa*), a geographical neighbor. The center of this area is, as nearly as may be, at Carmel-by-the-Sea, where is stationed a laboratory of the Carnegie Institution of Washington. The detailed descriptions of California trees in JEPSON'S *Silva of California* render minutiae unnecessary, though it may be noted in passing that among the teratological observations no mention is made in this work of the peculiarities to be noted below.

Carmel is situated in a forest of *Pinus radiata*, not, however, to the advantage of the tree. It is becoming more and more overcome by borers and fungi. It is, in any event, a short-lived tree of small dimensions but very rapid growth, a fact of importance in the present connection. It grows readily under cultivation, and

is very commonly seen in gardens, having either started by chance or by being planted. It is even used as a hedge plant, though of indifferent value for the purpose. But this circumstance leads often to the trimming of young trees, and so enables us to judge of the relative effect of traumatic stimulus as compared with another, namely, the amount of soil water, in producing unusual responses.

It must be prefaced that the amount of soil water in the normal habitat of this pine runs down very markedly during the long growing season, in spite of the moisture-laden atmosphere. Exact measurements are lacking, but the fact is sufficiently evident from the behavior of the vegetation in general, which becomes during the summer months of a distinctly xerophytic character. To this condition is due the gradual reduction in length of the fascicled leaves toward the apex of the season's growth, giving to the foliage of the leaders a cone-on-cone profile. PHILLIPS[1] has observed the same fact in *Pinus cembroides* Zucc., the Mexican piñon, in the mountains of southern Arizona, in a habitat which may, as regards soil moisture at any rate, be compared pretty closely with Carmel.

When grown in gardens, however, it generally happens that a greater abundance of water is provided, toward which a marked response is shown, both in amount of growth and in abnormal behavior. This is most obvious in an open spot used as an experimental garden within the grounds of the Carnegie Laboratory. Here the soil is kept abundantly supplied with water from springs, and here grows a cluster of young trees with heights ranging up to 30 feet or over. Aside from the generally well developed character of these, they all have fascicles which in the majority of cases proliferate. So numerous are the resulting short shoots that the branches become densely clothed, enough so as to quite hide the parent shoot itself from view when looked at from above.

Interest attaches to the phenomenon less because of the morphological fact, since it has long been known that pine fascicles do sometimes proliferate,[2] than because of their abundance and the

[1] Plant World **14**:66. 1911.

[2] For the literature on this see THOMSON, R. B., The spur shoots of the pines (to appear in the next issue of this journal), the manuscript of which the author has kindly allowed me to see.

regularity and constancy of their production. They appear, not, as might be expected, when the fascicles are young, but in those three or four years old especially. Unlike the lateral shoots of the whorls of branches, they are always negatively geotropic. This feature is brought out sharply in pl. XIV, *B*, which shows a length of a three-year old branch between whorls. The fact that fascicles as old as three or four years can renew their youth is worth notice. Those of *Pinus Taeda* in Alabama have been found to proliferate after two years, having been stimulated to grow from injury by cattle. This was in the cases of a couple of small trees which were six or eight years old. So far as I have been able to observe, in no instances do the abnormally developed spur shoots become permanent branches in *Pinus radiata*, although that there is evidently nothing in their nature to prevent further development appears from the fact that such is the case in *Pinus Taeda* (fig. 2, *B*). I have thought that the rapid rate of growth of the parent branch and the smallness of the spur shoots rendered successful histological articulation difficult, discrepancies which would be reduced if the parent branch is small to begin with, and of not rapid growth, as is true of *P. Taeda*.

Another example, and a still more striking one, I found at Carmel in the yard of Mr. SLEVIN, who kindly made a photograph for me. Except below, it was entirely without whorls, though a few extra-verticillate but ill-developed branches had grown. This abortion of whorls is quite common in this tree, but has been seen in other Coniferae (PHILLIPS, *loc. cit.*). The tree was growing quite near a cesspool. As the photograph shows, the whole of the chief stem (save for a small stretch) was densely clothed with foliage, due to the proliferation of nearly every fascicle, so that a fox-tail effect was produced. In the lower part of the stem, at the level of the bottom of the photograph, the spur shoots were dying and dropping off. Above they were growing, and the longest had attained a length of several centimeters. It was evident, however, that they were not able to become permanent in character, and there was no evidence that any of the branches had originated from fascicles.

I found no other such examples. Occasionally in small trees

which had been trimmed I saw a tendency for the fascicles to proliferate, but it was quite evident that pruning is by no means as efficient a factor as water supply. At the same time, we are bound to note that precisely where such a supply is abundant, and, in a remarkable case shown in fig. 1, where nitrogen in some form must have been quite plentiful, the development of verticillate branches was arrested. Other cases of absence of whorls were noted at Carmel, but only in gardens, though we know them to occur in nature

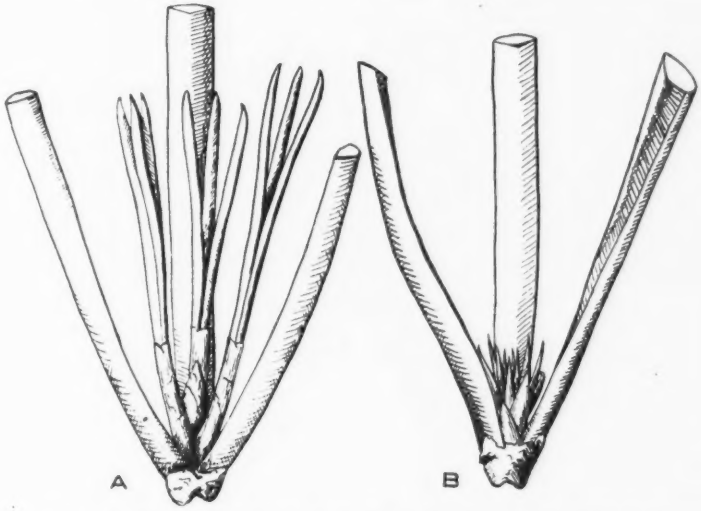


FIG. 1.—Proliferated spur shoots of *Pinus radiata: A*, the shoot so formed produced fascicles at once from the axils of the fascicled leaves of the spur shoot; *B*, hypertrophied scale leaves produced on the proliferating axis.

in other species. It is evident, however, that it is not due to less favorable soil conditions even here, since PHILLIPS (*loc. cit.*) notes that arrest of whorl development occurred in *Abies* on moist, rich sites in Arizona. One may conceive, furthermore, that a very rapid and energetic development of a chief shoot, especially in one in which the lateral shoots are not even laid down during the earlier part of period of growth, might be held responsible for failure to produce the usually formed lateral shoots.

Analogy in support of this view is not wanting, in general support of which may be cited also the apparently rather ready production of proliferations from spur shoots, with or without injury, in pine seedlings found by THOMSON. These seedlings grew in nurseries, probably under unusually favorable conditions for this

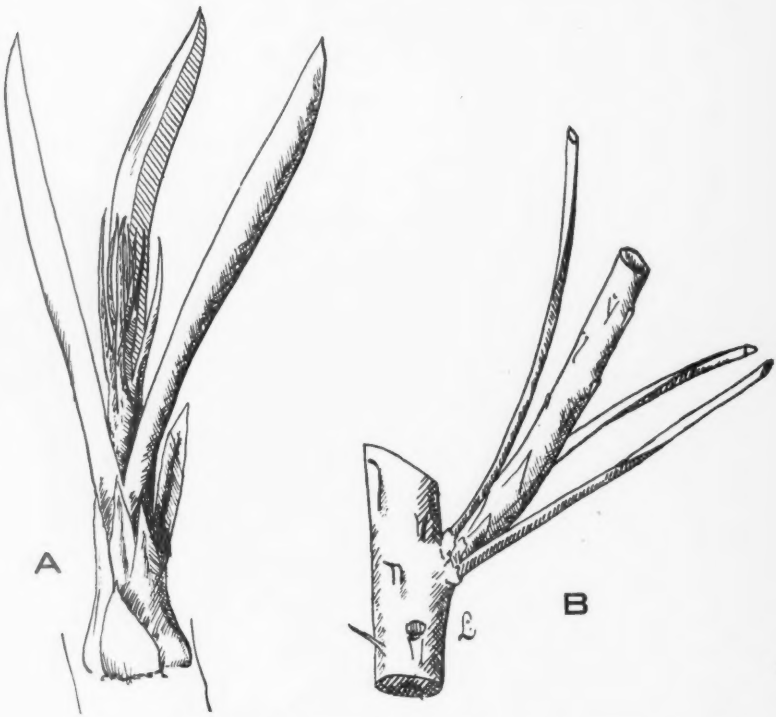
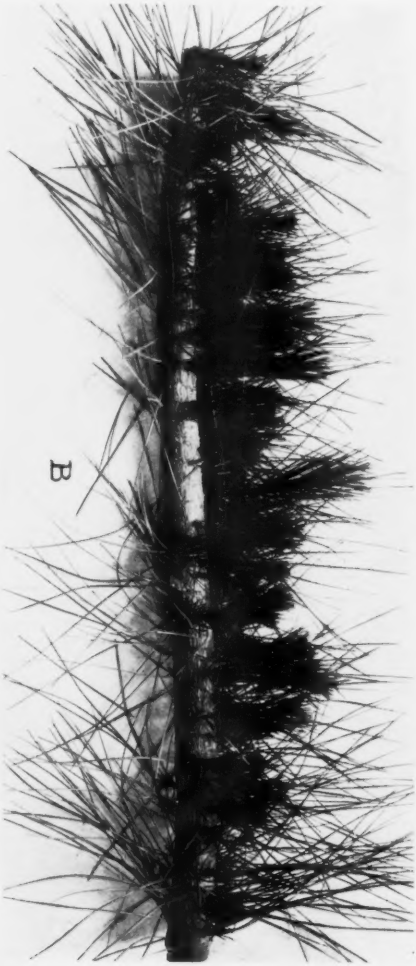


FIG. 2.—Proliferated spur shoots of *Pinus Taeda*: *A*, development of the axis below the whorl of fascicled leaves; *B*, a permanent branch formed by proliferation.

reason, especially as regards water supply. The likelihood that the spur shoots of mature trees do not proliferate, or if so more rarely than those of young trees or seedlings, is little lessened by my observations of *Pinus radiata*, since the trees were all young, or at any rate were not mature.



LLOYD on PINUS RADIATA

The character of the shoot produced by proliferation of the fascicular bud is worth further notice. As seen by the text figures, the leaves succeeding immediately on the fascicled leaves may be either true scale leaves (fig. 2, *A* and *B*), or the same hypertrophied (fig. 1, *B*), and hence of juvenile character; or again, new fascicles may be produced at once in the axils of the three leaves of the parent fascicle (fig. 1, *A*), thus showing that fascicled leaves may subtend axillary buds. Far more rare than any of the preceding is the elongation of the axis of the spur shoot below the fascicled leaves instead of that above, as I found to occur in *P. Taeda* after injury. In such cases the leaves of the fasciculate whorl (fig. 2, *A*) do not attain their normal shape and dimensions, but are wider at the base and taper somewhat toward the apex, thus approaching hypertrophied scale leaves in form. Here, therefore, we have arrested fasciculate leaves and over-developed scale leaves approaching a common type, which probably simulates the form of the scattered leaves of the progenitors of the pines.

From the point of view of comparative morphology, it seems logical and in accordance with the facts to argue with THOMSON that the type of fasciculation seen in *Pinus* is a highly specialized condition, derived from a prototype in which the spur shoots are not limited in growth. As THOMSON, however, has taken up this question in the paper referred to, I leave it here. The degree of physiological plasticity displayed by various species of the genus, and especially the amount shown by particular ones, notably *Pinus radiata*, argues, in my own mind, for a comparatively recent origin of the kind of spur shoot characterizing it. The evidence above cited appears to favor the view that abundance of water is of prime importance in disturbing the ordinary equilibrium, and thus stimulating the proliferation of spur shoots.

MCGILL UNIVERSITY

EXPLANATION OF PLATE XIV

A, small tree of *Pinus radiata* from which are absent the normal whorls of branches; the dense fox-tail effect is due to very numerous proliferated spur shoots; *B*, piece of a branch of another tree of the same species, showing the numerous proliferating spur shoots.

LIFE HISTORY OF PORELLA PLATYPHYLLA

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 184

FLORENCE L. MANNING

(WITH PLATES XV AND XVI)

There was no definite knowledge of the morphology of *Porella* until CAMPBELL (3) published an account of the life history of *P. Bolanderi* in 1904. Under the name *Madotheca*, LEITGEB (7) published a few figures of the apical situation. ENGLER and PRANTL (5) barely mention the group to which it belongs, and in their classification it receives the name *Bellincinia* (under the group Bellincinioideae). From 1904 to 1908, the literature is bare of any mention of *Porella*, that is, so far as its life history is concerned. In 1908, ANDREWS (1) accidentally discovered an abnormal situation in the archegonium, finding one with two axial rows, each containing the same number of neck canal cells, and each with a ventral canal cell and an egg. He reported the fact without drawing any conclusion as to its probable meaning. All investigators who have worked with *Porella* agree in regarding it as of high rank among the acrogynous Jungermanniales.

MATERIAL AND METHODS.—The material for the present investigation was collected by Dr. W. J. G. LAND, and some of it had been in the laboratory in a dried condition for several years. In order to revive it, it was soaked for 24 hours in water at a temperature of about 31° C. At the end of this period, it was as fresh as though it had never been dried; and the subsequent examination of the imbedded material showed that it had suffered no ill effects. This ability of liverworts to revive after a long period of desiccation has long been known. CAMPBELL (2) experimented with some Californian liverworts and found them able to recover after having been dried for months. No satisfactory explanation of this phenomenon has been given. GOEBEL (6) mentions the various devices of leafy liverworts for holding water for a long period, such as tubers, water sacs, etc., but this does not explain the power of revival after desiccation.

After the material had been revived, the branches bearing sex organs and those bearing sporophytes were killed in 0.25 per cent chromo-acetic acid, imbedded, and cut in sections 6–8 μ thick. The stains used were safranin, gentian-violet, and orange G; safranin and anilin blue; and iron alum-hematoxylin.

APICAL CELL AND VEGETATIVE BODY.—The apical cell is pyramidal, a type found throughout the Jungermanniales. By pyramidal is meant a cell whose cross-section is an isosceles triangle, and that has three cutting faces. Branches may arise from the latest segment of the cutting cell (fig. 1).

The leafy body is dorsiventral and recumbent, with two dorsal leaves and one ventral leaf (amphigastrium). The dorsal leaves have ventral lobes, which give to the ventral surface the appearance of having three rows of leaves.

The sex organs are borne on short lateral branches, those bearing archegonia being shorter than those bearing antheridia. The sporophyte is surrounded by a cluster of broad leaves.

ARCHEGONIUM (figs. 2–9).—The archegonium arises as a papillate cell from the segment of the apical cell or from the apical cell itself. The first division is transverse; the inner cell is the stalk cell, which does not divide until late in the development of the archegonium; the outer cell forms the archegonium. The first division of this outer cell is vertical, followed by two more vertical walls in rapid succession, cutting off a central cell. Transverse division of the central cell results in the cap cell and the cell which produces the axial row. Divisions of the peripheral cells form a jacket about the central cell and its progeny. The axial row comprises 4–6 neck canal cells in addition to the ventral canal cell and egg.

In the material studied, there was found an abnormal archegonium such as ANDREWS (**1**) reported (fig. 9). Whether such an archegonium has any bearing upon the question of the origin of the archegonium or not remains to be seen. In any event, it would fit well into the series of hypothetical sketches by DAVIS (**4**), connecting a gametangium ("plurilocular sporangium") of the brown algae with an archegonium of the liverworts. Miss LYON (**8**) has described cases of archegonia among the pteridophytes with lateral multiplication of the cells of the axial row.

ANTHERIDIUM (figs. 15–27).—The antheridium arises as a papillate cell from a segment of the apical cell, but never from the apical cell itself. The first division is transverse, the inner cell being the stalk cell, and the outer cell producing the spermatogenous cells and the jacket. The next wall may divide the stalk cell transversely, or both stalk cell and outer cell may divide vertically. If the first division of the outer cell is not by a vertical wall, vertical walls appear in the next two divisions. Periclinal walls then differentiate jacket and spermatogenous tissue. The jacket becomes several cells thick by periclinal divisions, and by further divisions the spermatogenous tissue appears as blocklike masses of cells. At maturity, the stalk of the antheridium is long and slender, and uniformly two cells in thickness.

SPOROPHYTE (figs. 10–14).—Only mature stages of the sporophyte were represented in the material. Great variation in the shape of the foot was observed, from the club-shaped foot illustrated by CAMPBELL (3) to a more or less definite anchor-shaped foot. There is no elaterophore, or any grouping of the elaters, but a general distribution of elaters through the capsule.

I am indebted to Professor JOHN M. COULTER and to Dr. W. J. G. LAND for advice and material during the progress of the investigation.

UNIVERSITY OF CHICAGO

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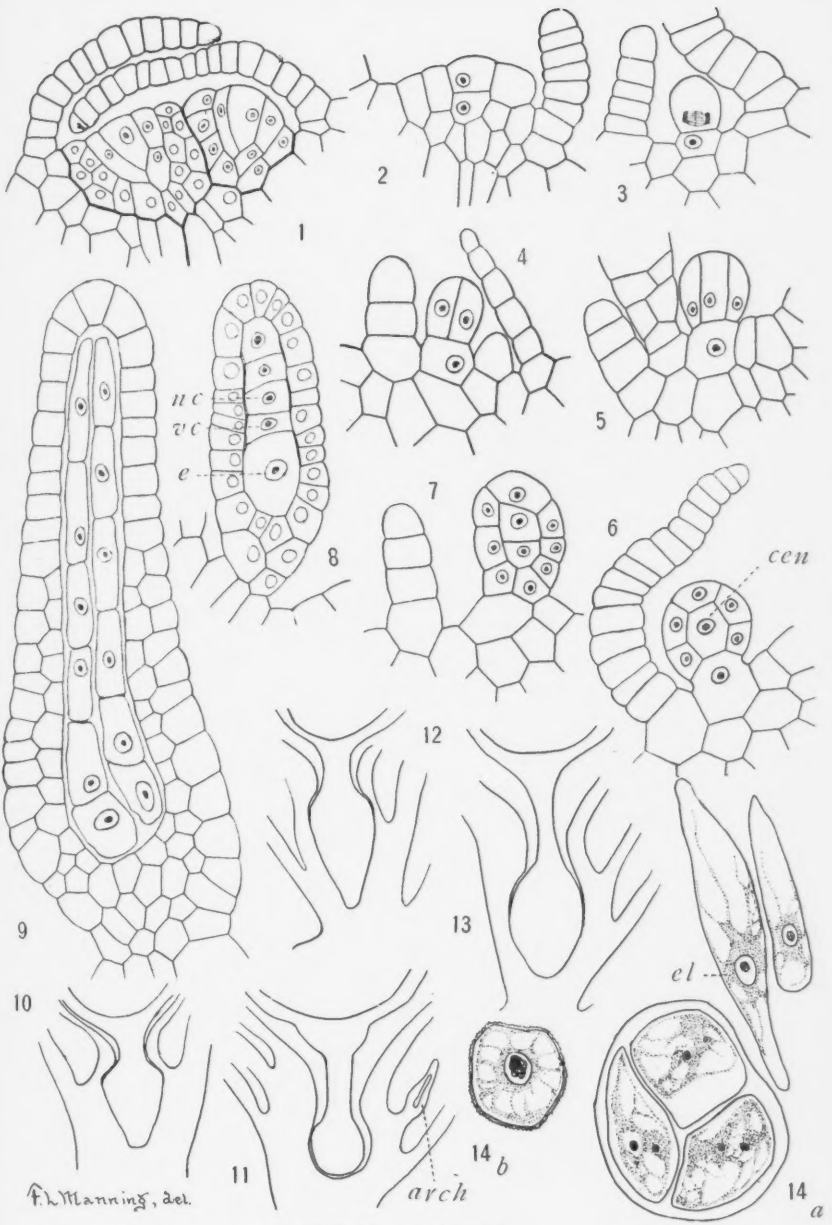
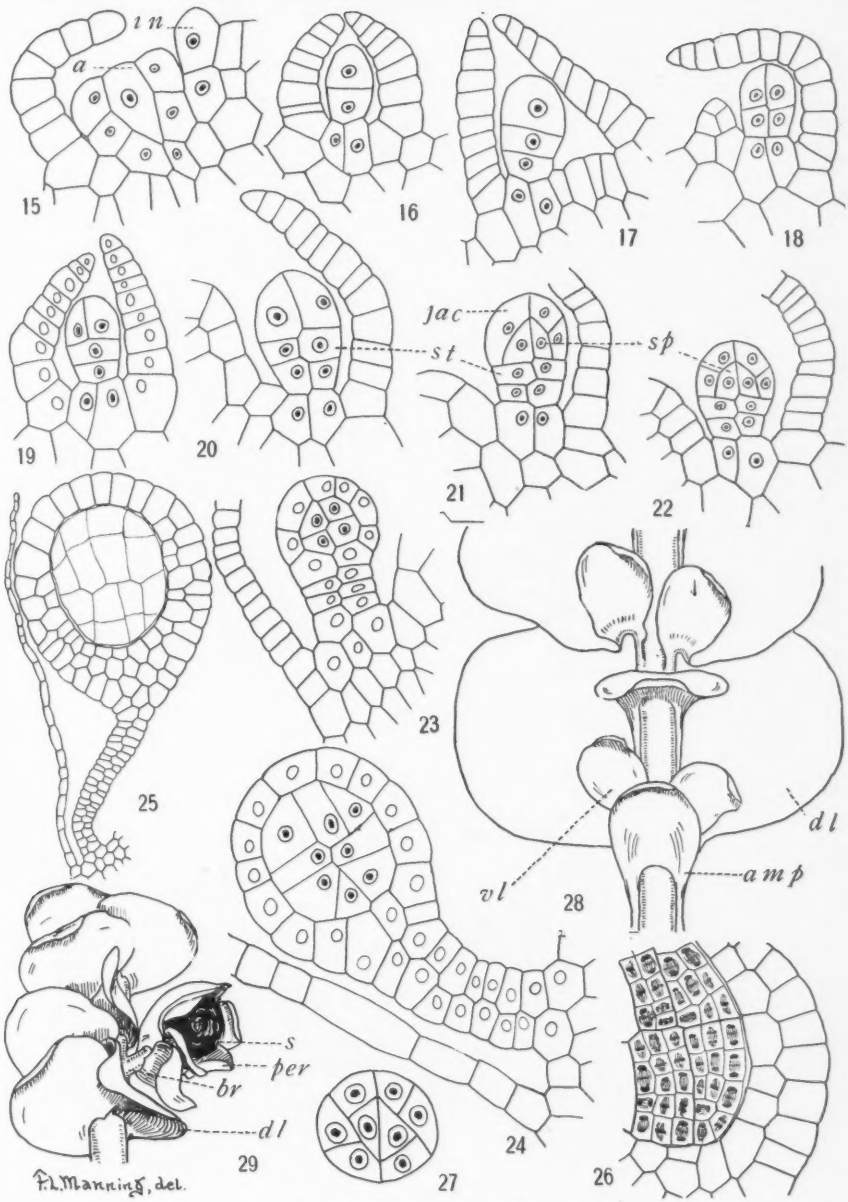


MANNING on PORELLA



MANNING on PORELLA

EXPLANATION OF PLATES XV AND XVI

All figures were drawn with a camera lucida, except figs. 25, 28, and 29, and reduced one-half in reproduction. The magnifications appearing in the plates are as follows: figs. 1–8, 14–24, and 27, ×329; figs. 9 and 26, ×115; figs. 10–13, ×22.5.

FIG. 1.—Apical cells, showing branching.

FIGS. 2–9.—Archegonium series.

FIG. 2.—First transverse division of initial.

FIG. 3.—Spindle of first vertical division.

FIG. 4.—First vertical wall in outer cell.

FIG. 5.—Second vertical wall; probably a third one in plane of plate completes the cutting-off of a central cell.

FIG. 6.—Central cell (*cen*) has cut off cap cell; peripheral cells have divided to form jacket.

FIG. 7.—First division of central cell.

FIG. 8.—The axial row, comprising three neck canal cells (*nc*), ventral canal cell (*vc*), and egg (*e*).

FIG. 9.—Mature stage of an abnormal archegonium showing two distinct axial rows.

FIGS. 10–14.—Sporophyte series.

FIGS. 10–13.—Various forms of the foot.

FIG. 14, *a*.—Sporogenous tissue at tetrad stage, before elaters (*el*) are coiled.

FIG. 14, *b*.—Mature spore before shedding.

FIGS. 15–27.—Antheridium series.

FIG. 15.—Antheridial initial (*in*) cut off from the last segment of the apical cell (*a*).

FIG. 16.—First transverse division of the initial cell.

FIG. 17.—The second transverse division; this division may be either transverse or vertical.

FIG. 18.—A case in which the second division was vertical.

FIG. 19.—In this case the second division was transverse, followed by a vertical division in the upper cell; the two lower cells are the stalk cells.

FIG. 20.—Vertical divisions of the stalk cells (*st*).

FIG. 21.—The first periclinal walls cutting off spermatogenous tissue (*sp*).

FIG. 22.—Further division of jacket cells; *sp*, spermatogenous tissue.

FIG. 23.—Division of spermatogenous cells by transverse walls.

FIG. 24.—Further division of spermatogenous tissue and elongation of stalk.

FIG. 25.—Mature antheridium showing blocking of spermatogenous tissue, division of jacket cells by periclinal walls, and the slender stalk consisting of two rows of cells.

FIG. 26.—Portion of a mature antheridium showing simultaneous division of spermatogenous cells.

FIG. 27.—Cross-section of antheridium at stage shown in fig. 22.

FIG. 28.—Ventral view of gametophyte with one of the amphigastria (upper one) turned back to show the lobing of the dorsal leaves; *amp*, amphigastrium; *dl*, dorsal lobe; *vl*, ventral lobe.

FIG. 29.—Dorsal view of gametophyte with one of the dorsal lobes (*dl*) turned back so as to show sporophyte branch (*br*); *per*, perichaetium; *s*, sporophyte.

THE EFFECT OF CLIMATIC CONDITIONS ON THE RATE OF GROWTH OF DATE PALMS

A. E. VINSON

(WITH ONE FIGURE)

The observations on which this study of the effect of climate on the rate of growth of date palms is based were made at the Cooperative Date Orchard, Tempe, Arizona, by F. H. SIMMONS, at the suggestion and under the supervision of Director R. H. FORBES of the Arizona Agricultural Experiment Station. The length of every leaf on four palms—two Deglet Noors and two Rhars—was carefully measured weekly during 1906 and 1907. By the system adopted the maximum error did not exceed one-quarter inch. In addition to the leaf measurements, daily records were kept of maximum and minimum atmospheric temperatures, and of soil temperatures at one foot, three feet, and five feet below the surface. A record of the level of the ground water was also kept, but this factor probably had no influence on the rate of growth, since the deeper roots were immersed in water at all times throughout the two years.

The data representing the weekly growth of all the separate leaves are too voluminous to use in their entirety. In most cases, after a new leaf has emerged well from the central bud, it makes the greater part of its growth in five or six weeks. After that the weekly growth, as shown by elongation, becomes much less, and finally appears as a negative quantity. This is due to the base of the leaves surrounding the entire stalk, which, as it expands, tends to draw the leaf as a whole lower down on the stalk. After repeated trials to obtain from this mass of data a series of consistent and comparable figures representing weekly growth, it was found that the sum of the elongation of the inner five leaves, that were unfolded sufficiently to be measured, gave the most satisfactory series. These were then calculated for each of the four palms and plotted as a curve, the ordinates of which represent the weekly growths (fig. 1). The maximum and minimum daily temperature,

and the daily soil temperature one foot below the surface at 7:00 A.M. are also plotted.

The temperature factor, as influencing the rate of growth, has other components than those expressed by maximum and minimum alone, because duration of temperature is of the utmost importance. The soil temperature is to a certain extent an index of all these, but in this case is modified by still other factors, such as evaporation. Continuous thermographic records were lacking, so that it became necessary to construct somewhat arbitrary ones. In the dry air and under the clear skies of Arizona the thermographic record is subject to relatively few variations from a normal form. In general the lowest point of the curve falls about sunrise, and the highest at 1:00 or 2:00 P.M. By the use of these points a fairly accurate thermographic record for this region can be drawn from the daily maximum and minimum temperatures. This alone, however, furnishes no usable data for the construction of a curve representing the total daily amount of heat received. If we assume some empirical temperature as that below which no marked growth takes place, and use this as a base line on the thermograph sheet, the areas lying above this line represent, at least relatively, the heat available for growth.

The selection of such a base line is not an easy matter, and at best must be somewhat arbitrary. The data obtained, however, will be relative and consistent on any base line chosen. For the present case 50° F. was selected, because the date palm does not seem to utilize temperatures below that, at least to any marked degree. Growth after the surface soil temperature reached 50° F. was practically nothing. This is not to be construed as meaning that no growth would occur at a uniform temperature of 50° F., but under actual climatic conditions the minimum temperature which would accompany a maximum of 50° F. would effectually inhibit growth. It will be noticed in this connection that during the first week of January 1906 growth was entirely inhibited, while during the winter of 1907, when the daily maximum was always above 50° F. and the minimum seldom below 30° F., growth never entirely ceased.

The curve representing the weekly heat-time areas, when plotted

along with those representing the growth of the palms, coincides in general with them, with one exception. Both years the rate of growth was maintained late into the fall considerably in excess of the amount of heat available. This may have been due to the continuance of the great activity which the plant experienced during the late summer and early fall months; that is, it was in better condition to utilize the available heat at this time than at a corresponding period in the spring.

The curves for the rate of growth show it to be the most active, not at the period of highest maximum, but rather at that of the highest minimum temperatures, which means warm nights. This falls in July, August, and sometimes September; and it is at this time that weakly palms recover their vitality. By far the greater part of the total yearly growth falls in the last half-year. The spring growth is much less luxuriant than the fall growth. The warm nights of July and August are due to the somewhat increased humidity, which prevents the usual rapid radiation after sundown. Humidity in itself is undoubtedly an important factor, but probably has less to do with the rate of growth of date palms than with other plants.

The chief relations of temperature to the rate of growth of date palms according to these measurements are: first, the period of maximum growth coincides with that of highest minimum rather than with that of highest maximum temperature, and this falls during the summer period of highest relative humidity; second, the rate of growth throughout the entire year is, in most cases, in proportion to the heat-time units over 50° F.

The rate of maturation of the fruit is probably influenced by the same factors as the rate of growth of the foliage. The effect of high minimum temperature in promoting the maturing and ripening of the Deglet Noor date has recently been called to the writer's attention by M. BRIQUEZ, the civil governor of Gafsa in Southern Tunis. The oasis of Gafsa, which lies not over 75 miles northeast of the Djerid region, where the finest Deglet Noor dates are produced, produces only second quality fruit. The difference in altitude between the two oases is about 900 feet, Gafsa being 1126 feet and Tozeur in the Djerid 197 feet. The two are separated by

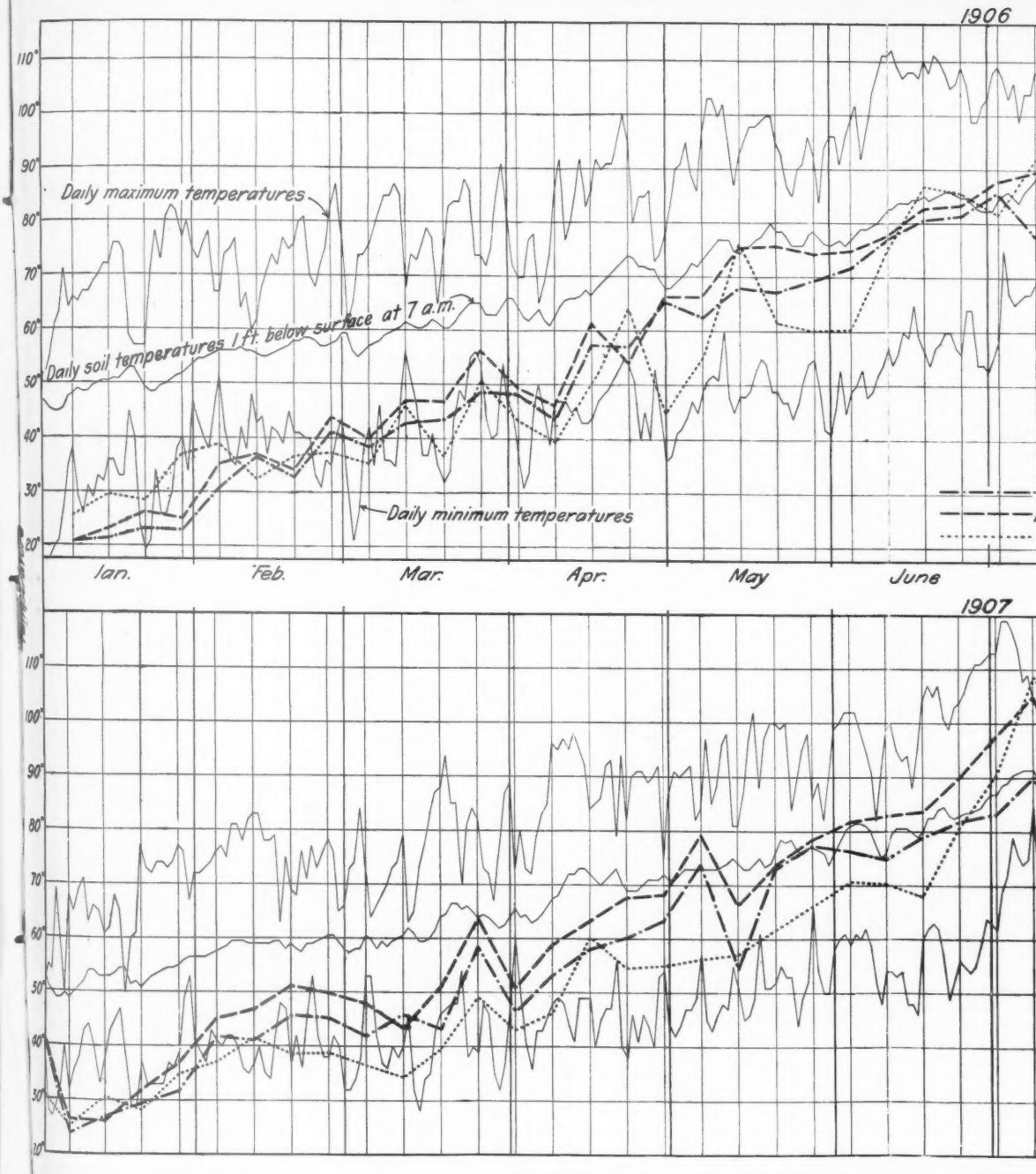
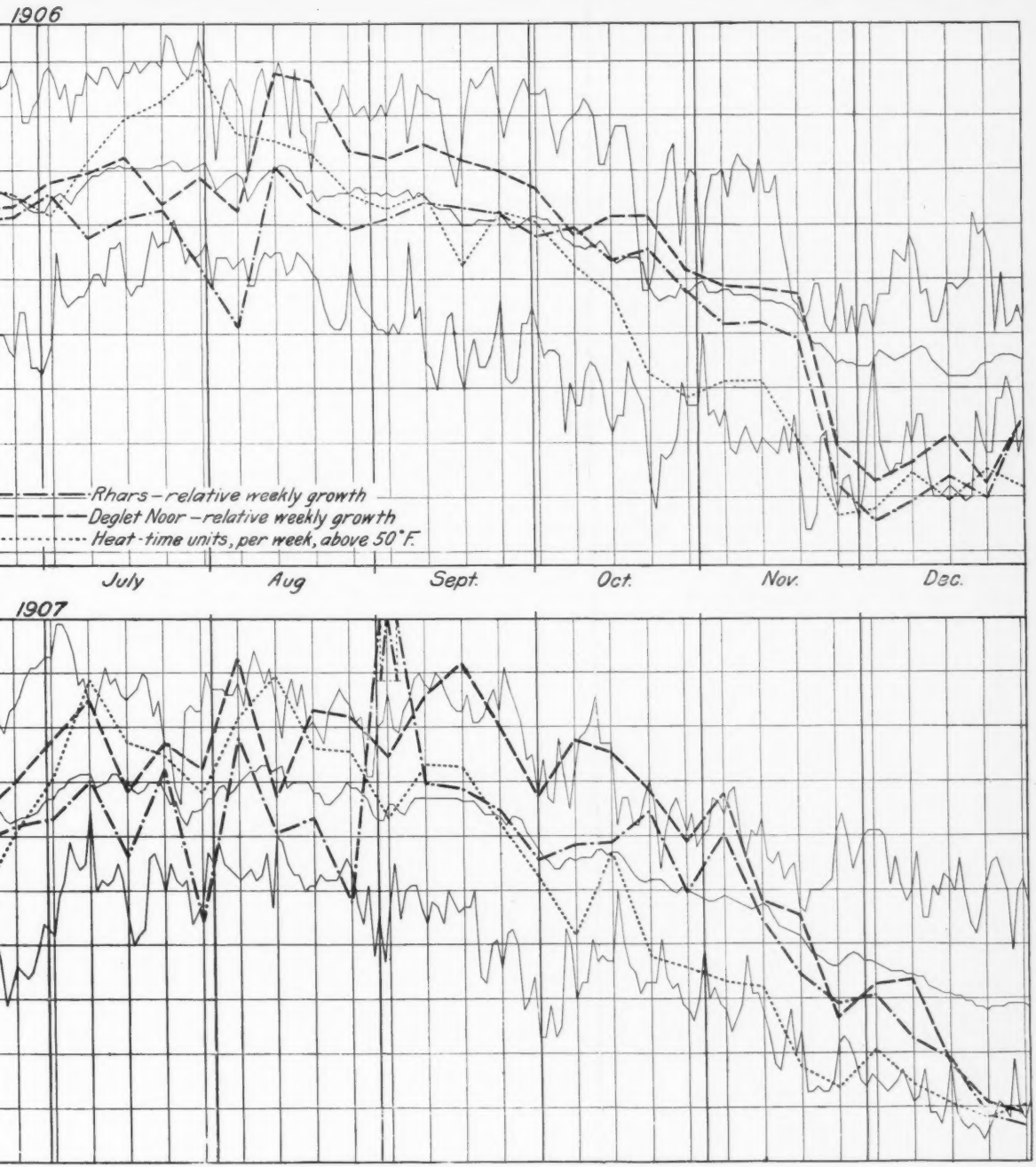


FIG. 1.—Curves showing the relation between temperature conditions a



e conditions and the rate of growth of Deglet Noor and Rhars date palm

several ranges of very low mountains, but the Djerid is exposed to the Sahara on the south. The result is that while the day temperatures at Gafsa are only 6 or 7° F. cooler than at Tozeur, the night temperatures vary by 30 or 35° F. Thus, high minimum temperature seems to be a more important factor in determining the maturation of the fruit than high maximum temperature. This observation is in perfect harmony with the curves for rate of growth obtained at Tempe, Arizona.

Arizona Agricultural Experiment Station
Tucson, Arizona

BRIEFER ARTICLES

THE TYPE SPECIES OF DANTHONIA

In a recent paper[1] by NELSON and MACBRIDE the generic name *Pentameris* Beauv. has been taken up for *Danthonia*, and our American species have been transferred with the corresponding new combinations. A quotation from this article explains the authors' reasons for these changes.

> As shown by PIPER in his "Flora of Washington" (Contrib. Nat. Herb. 11:122), the name *Danthonia* is not available for the American species that have passed under that name. In choosing among the several later names that have been proposed, he selects *Merathrepta* Raf. in Seringe, Bull. Bot. 1: 221. 1830, apparently because the type species of the genus was *M. spicata*, an American species closely congeneric with ours. But will this fact permit our ignoring *Pentameris* Beauv. Agrost. 92. *t. 18.* 1812, the type species of which is accepted as a *Danthonia*, as that genus has until lately been understood?

I think the authors are justified in taking up *Pentameris* Beauv. in place of *Merathrepta* Raf., but I do not agree with them nor with PIPER in rejecting *Danthonia*, and I take this opportunity of recording my reasons for retaining the latter name. NELSON and MACBRIDE apparently have not investigated on its merits the validity of *Danthonia* for our species, because they say "as shown by PIPER." In the article cited, PIPER merely states: "The type of *Danthonia* DC. is *Festuca decumbens* L. (*Triodia decumbens* R. Br.), and the name cannot therefore be used in the current sense. *Merathrepta* has for its type *M. spicata* (L.) Raf. (*Avena spicata* L.)." With this statement I do not agree, and I will give my reasons. I believe that stability in botanical nomenclature is greatly aided by the adoption of the type method; that is, that for nomenclatorial purposes a genus shall be based upon a type species and a species upon a type specimen. The selection of the type species of a genus fixes the application of the generic name to the group containing the type species. It is easy to determine the type species if the genus is monotypic or if the author has indicated the type. In other cases it

[1] Western plant studies II. BOT. GAZ. 56:469. 1913.

may be easy to select the type from several species by some statement of the author or because one species was figured. There are cases in which a careful weighing of evidence is necessary to determine the species which the author had chiefly in mind when establishing the genus, that is, the type species. On account of the bearing it may have on the selection of type species, I give here, somewhat fully, the evidence which leads me to select *Avena spicata* L. instead of *Festuca decumbens* L. as the type species of *Danthonia* DC.

DeCandolle[2] establishes the genus *Danthonia* in a local flora and hence describes only the two species growing in France. These are (1) *D. decumbens*, based upon *Festuca decumbens*, and (2) *D. provincialis*, a change of name for *Avena calycina* Vill. In a note at the end of the generic description, and preceding the descriptions of the species, is the following: "On doit, outre les espèces décrites plus bas, rapporter à ce genre, 1°. avena spicata L. ou avena glumosa Michaux; 2°. avena calicina Lam. non Vill." It is evident from this note that the author included these two species in his idea of the genus *Danthonia*. The only reason for selecting *D. decumbens* for the type of the genus is that it is the first of the two species described. There are more and better reasons for selecting *Avena spicata* as the type. It is the first species mentioned and it represents better than *D. decumbens* the generic idea. In regard to the last point, it is to be noted that the generic description states that the lemma ("valve externe") is provided with an awn, sometimes long and twisted, sometimes rudimentary (à demi-avortée). DeCandolle differentiates *Danthonia* from *Melica* by the presence of the awn, and from *Avena* by the position of the awn, and by some other characters. It is evident that the author considered the awn to be one of the important distinguishing characters of his new genus. Three of the four species mentioned by DeCandolle are congeneric and possess a well marked awn. In the other species, *D. decumbens*, the awn is rudimentary ("les valves externes des balles ont au sommet une echancrure d'où part un rudiment d'arête") and hence this species, inasmuch as it departs from the general idea of the genus, should be excluded from consideration in the selection of the type. For the reasons given I favor selecting *Danthonia spicata* (L.) DC. as the type species of *Danthonia*, thus retaining this generic name for our American species. *Festuca decumbens* L. is generally recognized as generically distinct and has been made the type of *Sieglingia*. Some botanists are inclined to select the type from among those species that from the standpoint of the author of the work

[2] In Lam. and DC. Fl. Franç. 3:52. 1805.

are natives. Other things being equal, it is well to do this. But even by this method, the type would be *D. provincialis* DC., as this corresponds better to the generic description than does *D. decumbens*. This selection of the type also retains the name in the traditional sense.—A. S. HITCHCOCK, *U.S. Dept. Agriculture.*

A METHOD OF HANDLING MATERIAL TO BE IMBEDDED IN PARAFFINE

(WITH ONE FIGURE)

The account given by Mr. W. DUDGEON under the above title (BOT. GAZ. **57**:70–72. 1914) has suggested that some might be interested in a similar, but simpler, method which I find useful.

The specimens to be imbedded in paraffine are strained from the killing solution into a small piece (2–4 inches square) of cotton chiffon held in bag form. The corners and sides are then drawn together and tied with a piece of sewing thread (about no. 50), making such a bag as is represented in fig. 1. All surplus chiffon is cut away and the bag is put for washing in a dish into which a rubber tube brings water slowly from a faucet. Any number of bags can be washed in one dish, their contents being labeled by a small slip of paper inclosed in the bag with the specimens. The end of the thread with which the bag is tied is left a few inches long, and by this the tiny bags can be lifted from one solution to another until the specimens are ready to be put into paraffine. The end of the thread left hanging over the top of the bottle does not interfere with replacing the stopper. When the specimens are ready for the paraffine, the bag is cut off just below the thread tie. It spreads open instantly as a flat piece of chiffon, from which the specimens can easily be transferred to the paraffine.

FIG. 1

The chiffon found best is the thin cotton quality usually sold at the veiling counter of department stores at 50 cents a yard; the meshes are 0.25–0.33 mm. in diameter. The material is so thin that the specimens are as good as free in the solution jars, yet any number can be handled with the minimum of labor and time.—ELDA R. WALKER, *University of Nebraska.*

A CORRECTION

In a review of the second edition of JOHANNSEN'S *Elemente der exakten Erblichkeitslehre* in the last number of this journal (BOT. GAZ. **57**:239. 1914), I made a very stupid error for which I wish to apologize to Dr. JOHANNSEN and to the botanical public. From the preface, in which JOHANNSEN disclaims being a "pure Weismannian," and from the sympathetic treatment of SEMON in one of the chapters on the influence of environment, I obtained the idea that he retained a Lamarckian attitude, although disclaiming belief in experimental proof of the inheritance of acquired characters. Oddly enough, other readers of the book gained the same impression, as I learned from various conversations. This phase of the subject being necessarily somewhat ancient biological history I passed it by rather hurriedly. Recently I have read the two chapters concerned carefully, and find that JOHANNSEN is even more of a Weismannian in his essential principles than I had thought. His wish not to be considered as a "pure Weismannian" evidently rests entirely upon his opposition to WEISMANN'S morphological conceptions, as I stated in the review.—E. M. EAST.

A CORRECTION

The new combination *Lobaria oregana* (Tuck.), made in BOT. GAZ. **56**:497. 1913, I find was published in *Flora* **47**:364. 1889, by MÜLLER, and therefore stands **Lobaria oregana** (Tuck.) Müll. Arg.—R. HEBER HOWE, JR.

CURRENT LITERATURE

BOOK REVIEWS

The flora of Western China

A most interesting account of the experiences of a naturalist in Western China during several years of exploration has been given by WILSON.[1] Much of the work deals with the manners and customs of the non-Chinese peoples inhabiting the borderland region that was being explored, but there is also a great deal of botanical material, as the result of four expeditions. An introduction is written by Professor CHARLES S. SARGENT, in which the tree families of Eastern North America and of China are contrasted. The general statement is made that the trees of Eastern North America are larger and more valuable than the related Chinese species, but that Chinese shrubs in general produce more beautiful flowers than those of Eastern North America. In considerable detail 129 families are presented, which occur in Eastern North America and in China. Of these, 92 families are common to the two regions; 12 occur in Eastern North America but not in Eastern Asia; and 25 occur in Eastern Asia but not in Eastern North America. In making a similar contrast with the genera, it is found that out of 692 tree and shrub genera in the two regions, 155 are common to both; while 158 occur in Eastern North America and not in Eastern Asia, and 379 are found in Eastern Asia and not in Eastern North America.

The first volume has chiefly to do with the topography of the region and the character and customs of the peoples inhabiting it. The material of botanical interest occurs chiefly in the second volume, the nature of it being indicated by the following chapter titles: the flora of Western China, a brief account of the richest temperate flora in the world; the principal timber trees; fruits, wild and cultivated; Chinese materia medica; gardens and gardening; favorite flowers cultivated by the Chinese; agriculture; the principal food-stuff crops; the more important plant products; wild and cultivated trees of economic importance; the more important plant products; cultivated shrubs and herbs of economic value; tea and "tea-yielding" plants; the tea industry for the Thibetan markets.

The book is very suggestive of the botanical "travels" of years ago, which have always been the first introduction of botanists to a new region.—J. M. C.

[1] WILSON, E. H., A naturalist in Western China. 8vo. 2 vols. pp. xxxvii+251 and xi+229. *figs. 111.* New York: Doubleday, Page & Co. 1913.

Flora of Manila

In no place in the tropics has botanical work made such great strides as in the Philippines. This is particularly true of the systematic botany work of the Bureau of Science under the energetic direction of ELMER D. MERRILL. Until recently no effort had been made to collect the numerous taxonomic papers into a flora for any particular region. *The flora of Manila*[2] is not a sufficiently comprehensive title, because the work really covers the flora of the more populated coastal regions of the entire archipelago. About 1000 species, or approximately one-sixth of the total number of species known from the islands, are described. These are distributed among 591 genera and 136 families.

The bringing together under one cover of one-sixth of the known flora of the Philippines will make useful a large number of descriptions of plants that heretofore have been practically inaccessible to anyone except the specialist. The usefulness of the work to the layman is enhanced by definition of terms used in descriptive botany (pp. 9–20), some remarks on classification (pp. 20–21), directions for preparing botanical specimens (pp. 21–23), some remarks on the preparation of the material for the herbarium (pp. 24–25), and a glossary of technical terms (pp. 25–33).

The flora includes practically all the species of vascular cryptogams and flowering plants growing naturally within the Manila district, and most of the cultivated forms both of Philippine and of foreign origin. In it one can find descriptions of nearly all the useful and ornamental plants of the Islands, except the timber trees.

It is to be hoped that the recent reorganization of the scientific staff of the Bureau of Science will not materially interfere with progress in this kind of work. Another five years ought to bring forth a flora of the Philippine Islands.—H. N. WHITFORD.

A plant physiology

A plant physiology by KOLKWITZ[3] offers several features that are novel for a book bearing its general title. Unusual emphasis is given to the lower forms; 60 pages are devoted to the physiology of "phanerogams" and almost 200 to the study of "cryptogams." This change of emphasis has the advantage of bringing into prominence such cosmic cycles as the nitrogen cycle without in any way detracting from an understanding of other physiological processes. The book, however, can hardly be called a plant physiology. It contains many

[2] MERRILL, E. D., The flora of Manila. pp. 490. Bureau of Science, Manila. 1912.

[3] KOLKWITZ, R., Pflanzenphysiologie, Versuche und Beobachtung en an höheren und niederen Pflanzen einschliesslich Bakteriologie und Hydrobiologie mit Planktonkunde. V. 8vo. pp. 258. *pls. 1–12. figs. 116.* Jena: Gustav Fischer. 1914.

pages of systematic descriptions in connection with the plankton work, including both plant and animal forms; plant morphology receives some attention, and bacteriological and plankton technique are more or less fully described. One is doubtful whether the physiological viewpoint even prevails.

The book is an outgrowth of exercises that have been used in teachers' courses for fourteen years, involving at least 25 repetitions. In spite of this, one is unable to judge whether it is more a laboratory manual or a descriptive text. It seems poorly suited for either.—WILLIAM CROCKER.

Diseases of tropical plants

COOK[4] has published a timely volume which introduces us in a compact way to the diseases of the tropics. The study of plant pathology has been chiefly with the crop plants of the temperate regions, but with the growing interest in tropical plants, there must come a knowledge of the tropical diseases. This vast field has yet to be developed, but the scattered literature that does exist should be brought together, and this COOK has done in a very effective way. The spirit of the book is modern, for instead of being merely a list of the parasites inducing diseases, there is a chapter on the nature and symptoms of diseases, and another on the structure and functions of plants. The classification of the disease-producing fungi is restricted to a single chapter, and then a series of chapters takes up the study of the best known tropical diseases. Two final chapters discuss prevention and control, fungicides and spraying apparatus.—J. M. C.

A weed flora

PAMMEL[5] has set the pace for a comprehensive book on the weed flora of a state. He makes the statement that a conservative estimate of the damage done to the crops of Iowa by weeds is $25,000,000 annually. If this is true, it is certainly high time the farmers should learn to recognize the dangerous weeds and eliminate them. The contents of the volume can be best indicated by the chapter titles. The first chapter is a descriptive manual (400 pp.), in which every weed is illustrated and its distribution through the state indicated upon a map. The remaining chapter titles are as follows: the general character of seeds; the microscopic structure of some weed seeds; morphology of flowers and leaves; scattering of weeds; roots and rootstocks of weeds; number and kind of weeds in different soils; injuriousness of weeds; weed migration; medicinal weeds; phenology of weeds; weeds and seed laws.—J. M. C.

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[4] COOK, M. T., The diseases of tropical plants. 8vo. pp. xi+317. *figs.* 85. London: Macmillan. 1913. $2.75.

[5] PAMMEL, L. H., The weed flora of Iowa. Iowa Geological Survey. Bull. no. 4. pp. xiii+912. *figs.* 570. 1913.

MINOR NOTICES

Index Filicum.—In 1905 CARL CHRISTENSEN published his *Index Filicum*, and now a supplement has appeared,[6] covering the period 1906–1912. The two parts are (1) the supplement, which contains all the names of ferns published during 1906–1912, and (2) corrections. In the supplement there are enumerated 33 names of new genera and subgenera that have been proposed. The number of species described as new during the period covered, and adopted in the supplement, is 1644. Eliminating the older species that have been reduced to synonyms, and adding the new ones, the number of species of ferns recognized by CHRISTENSEN at the end of 1912 is 7411.—J. M. C.

The fresh-water flora of Germany, Austria, and Switzerland.—Part 14 of this series of brochures has now appeared.[7] The four previous parts have been noted in this journal.[8] The present part presents the Bryophytes, and the keys, descriptions, and excellent illustrations should make their identification comparatively easy. The genera and species presented under the three groups are as follows: Sphagnales, 48 species; Bryales, 50 genera and 131 species; Hepaticae, 25 genera and 60 species.—J. M. C.

NOTES FOR STUDENTS

Natural vegetation and crop production.—In a careful study in one of the broad valleys in the Great Salt Lake Basin, KEARNEY[9] and his associates have shown that the natural vegetation of the area is so reliable an indication of the physical and chemical conditions affecting plant life that it affords an excellent basis for estimating the capabilities of the land for crop production. The report gives a good example of the quantitative investigation of the moisture and salt contents of the soil and the efficiency of the wilting coefficient in expressing the relation of the soil moisture to plant life and growth. Nearly all of the plant associations considered are dominated by a single species and very definitely limited in their extent.

The sagebrush (*Artemisia tridentata*) association is found in the higher portions of the valley. With an average precipitation of 40 cm., the growth-water is exhausted early in the summer, as shown by their determinations, but there is no excess of alkali salts. A good development of this association

[6] CHRISTENSEN, CARL, Index Filicum. Supplementum 1906–1912. pp. 132. Hafnia, Denmark: H. Hagerup. 1913.

[7] PASCHER, A., Die Süsswasser-Flora, Deutschlands, Österreichs, und der Schweiz. Part 14. Bryophyta, by C. H. WARNSTORF, W. MONKEMEYER, and V. SCHIFFNER. pp. 222. *figs. 158*. Jena: Gustav Fischer. 1914. *M* 5.60.

[8] BOT. GAZ. **56**:233. 1913.

[9] KEARNEY, T. H., BRIGGS, L. J., SHANTZ, H. L., and others. Indicator significance of vegetation in Tooele Valley, Utah. Jour. Agric. Research **1**:365–417. 1914.

indicates land well adapted to both dry and irrigation farming, the taller and thicker the sagebrush the richer the soil.

Areas next below the sagebrush are occupied by the *Kochia* (*K. vestita*) association, and this was found to indicate a soil of finer texture, with similar moisture conditions, but with only the first foot of soil free from an injurious quantity of alkali salts. Dry farming does not succeed on this area because of the small amount of soil free from alkali, while the relatively impervious nature of the soil prevents the washing out of the alkali by irrigation; hence *Kochia* land scarcely permits crop production.

Following the *Kochia* belt comes the shad scale (*Atriplex confertifolia*) association, with soil moisture and alkali conditions similar to the preceding, but with a soil containing much gravel. Here dry farming does not succeed, but with irrigation the alkali would be more readily washed out and hence the crop probabilities are better.

The study continues with the associations of the lower, more alkaline areas, indicating as before the agricultural possibilities of the land. In addition to the value of the various associations as crop indicators, their composition is detailed, the successions noted, and the root characters of the principal species studied. The report is an excellent example of applied ecology.—G. D. FULLER.

The ecology of Calluna.—The common European heather, *Calluna vulgaris*, has been regarded as a typical calciphobe by CONTEJEAN and other partisans of the chemical as opposed to the physical theory of plant distribution. Furthermore, the heather is regarded as partial to acid soils, which also are deficient in certain mineral constituents, and hence are betokened sterile. *Calluna* occurs in various places on the chalk downs of southern England, being accompanied by several other species that are alien to the ordinary flora of the chalk; usually the heather patches are sharply delimited from the surrounding chalk associations. Miss RAYNER[10] has been making some detailed investigations of *Calluna* on the downs, and although much remains to be explained, a large contribution has been made to the ecology of the species. On the downs the heather grows in neutral soil, rich in most ordinary mineral constituents, but poor in lime; the roots, however, often penetrate down into soil areas that are rich in lime. The proportion of magnesia is relatively high. Cultures were made in soil from the heather areas and in ordinary chalk soil containing over 40 per cent of calcium carbonate. In the latter soil there were noted certain abnormalities, such as reduced capacity for germination and arrested development of the various organs; extensive bacterial colonies developed about the roots, and the mycorhizal fungus developed poorly. The relation of *Calluna* to its root fungus is obligate; the primary root becomes infected

[10] RAYNER, Miss M. C., The ecology of *Calluna vulgaris*. New Phytologist **12**: 59–77. *pl. 1. figs. 2.* 1913; see also preliminary paper, *ibid.* **10**: 227–240. *figs. 2.* 1911.

shortly after germination, the mycelium coming from the seed coat which is infected while still in the ovary. In sterile cultures there is a complete arrest of root development. It is concluded that the so-called soil preference of *Calluna* depends upon the maintenance of a biological balance between the roots and the root fungi. The disturbance of this balance in soils rich in lime is responsible for poor growth in such soils. Probably also the increased bacterial growth in the chalk cultures is detrimental. It is to be hoped that the author will make a comparative study of *Calluna* in its ordinary habitat, where the soil is acid and infertile.—H. C. COWLES.

A new Tylodendron.—WEISS[11] has described a new form of *Tylodendron* under the name *T. Cowardi*. Particular interest in this specimen centers around the secretory canals and primary wood. WEISS says: "The outer portions of the pith have very numerous secretory canals with dark brown contents, very like those found in the Medullosae, in cycads, and also in the pith of *Poroxylon*. These have not been observed or described, so far as I know, in any other specimens of *Tylodendron* showing structure." There are also isolated groups of primary xylem at the periphery of the pith as in *Pitys antiqua*, but much smaller. Analogous structure is seen in *Mesopitys* of ZALESSKY and in *Cycadeoidea* of WIELAND. With regard to the systematic position of this *Tylodendron*, WEISS agrees with POTONIÉ that *Tylodendron* is of araucarian affinity. He considers that the pitting of the secondary wood, the double leaf traces, etc., are araucarian or cordaitean in character, and homologizes the secretory ducts in the pith with those in the same region of the cone of *Araucaria* and the stem of *Poroxylon*. WEISS further considers that since a *Tylodendron* has recently been described with discoid pith like the Cordaiteae, considerable light is thrown on the connection between the cordaitean and the araucarian forms, and that the study of this genus promises much along this line in the future.—R. B. THOMSON.

Plant invasion on Hawaiian lava flows.—Thanks to the initiative of TREUB, we are now well informed as to the revegetation of Krakatau. The successive lava flows from Mauna Loa, the age of many of which is exactly known, afford an excellent opportunity for comparable investigations. The results of a preliminary study of this sort are given by FORBES.[12] As is well known, the lava here is of two well defined sorts, the *pahoehoe*, which has a smooth and satiny exterior and may be ropy, and the *aa*, which has a cavernous and jagged exterior. On a lava flow of 1859, no vascular plants were found on the *aa*, though the surface was often white with lichens. To FORBES' surprise,

[11] WEISS, F. E., A *Tylodendron*-like fossil. Mem. Proc. Manchester Phil. Soc. **57**: pp. 14. *pls.* 2. 1913.

[12] FORBES, C. N., Preliminary observations concerning the plant invasion on some of the lava flows of Mauna Loa, Hawaii. Occasional papers of the Bernice Pauahi Bishop Museum of Polynesian Ethnology and Natural History **5**: 15–23. 1912.

the smooth *pahoehoe* was much more richly covered with vegetation, which occurred, however, only in cracks. On a 1907 flow plants were found just beginning to be established. The author concludes that on both types of lava, the first pioneers are lower cryptogams; on the *pahoehoe* these are soon succeeded by ferns and seeds plants, but on the *aa* there is a long-enduring lichen stage. Ultimately the natural forest of the region returns, except in places where man's influence causes the successful invasion of a naturalized flora. The *ohia* (*Metrosideros polymorpha*) is the dominating tree at first, and the *koa* (*Acacia koa*) is the dominating tree of the ultimate or climax forest.—H. C. COWLES.

Rainfall and soil moisture.—In studying the conditions which govern the plant activities of the semi-arid region about the Desert Laboratory, Tucson, Arizona, SHREVE[13] has made weekly determinations of the soil moisture at depths of 3, 15, and 30 cm. throughout the year, and compared the resulting data with the record of the rainfall for the same period, in order to see exactly how the former is affected by the latter. It is evident that precipitation of less than 0.15 inch has no effect upon the soil moisture, and that therefore there are periods of 140 days in the region under consideration without rainfall of sufficient amount to increase the moisture in the soil. This serves to indicate that in desert regions by no means all of the small rainfall is significant to vegetation as a source of water supply. The evaporation has been determined and plotted along with its ratio to the soil moisture, the march of soil moisture throughout the year, and the distribution of rainfall, making an instructive and detailed chart of those moisture factors which affect vegetation. Among other things it proves the range of moisture conditions at the Desert Laboratory to be one of great extremes.—G. D. FULLER.

Drought resistance in Hopi maize.—For centuries the Indians of New Mexico and Arizona have grown a race of maize in soil that is much too dry for the ordinary races of the species. A large factor in the success of this race, known as Hopi maize (from the Hopi Indians), is the extraordinary capacity for elongation possessed by the mesocotyl.[14] The Indians are accustomed to plant their maize at a depth of 15–45 cm.; this depth is for most varieties too great for effective germination. In ordinary races the mesocotyl can rarely be forced to grow to a length greater than 10 cm., whereas a length of 36 cm. can be induced in Hopi maize. Another advantage in the mesocotyl of Hopi maize is its ability to produce roots, a rare phenomenon in grass internodes. A third feature of great importance is the great elongation of the primary root

[13] SHREVE, F., Rainfall as a determinant of soil moisture. Plant World 17:9–26. *figs. 3.* 1914.

[14] COLLINS, G. N., A drought-resisting adaptation in seedlings of Hopi maize. Jour. Agric. Research 1:293–302. *figs. 2. pls. 29–32.* 1914.

in Hopi maize. However these striking features may have originated, it is obvious that they enable this race to grow in much more arid situations than other races of maize, and it is suggested that it may well become an important economic plant in arid regions.—H. C. COWLES.

Indiana Academy of Science.—The volume of *Proceedings* for 1912 contains the following abstracts and papers of botanical interest: "Further notes of the seedless fruits of the common persimmon (*Diospyros virginiana* L.)," and "The influence of certain environic factors on the development of fern prothallia," by DAVID M. MOTTIER; "The mosses of Monroe County," by F. L. PICKETT and MILDRED NOTHNAGEL; "Length of life of *Arisaema triphyllum* corms," and "Acetic alcohol as a killing and fixing agent in plant histology," by F. L. PICKETT; "Plants not hitherto reported from Indiana," by CHAS. C. DEAM; "Report of the work in corn-pollination, IV," by M. L. FISHER; "Conjugation in *Spirogyra*," by F. M. ANDREWS; "Photosynthesis in submerged land plants," by H. V. HEIMBERGER; "Indiana fungi, III," by J. M. VAN HOOK; "Fungous enemies of the sweet potato in Indiana," by C. A. LUDWIG; "Notes on some puff balls of Indiana," by FRANK D. KERN; "The improvement of medicinal plants," by F. A. MILLER; "The structure and diagnostic value of the starch grain," by R. B. HARVEY.—J. M. C.

Structure of tropical amphibious plants.—Material of *Ipomea reptans* and *Neptunia prostrata* obtained from pools in northwestern Madagascar that are quite dry during a considerable portion of the year was examined by CHOUX,[15] who compared the anatomy of the portions developed during the wet and dry seasons. He found considerable differences in size and external appearance, while in internal structure the stems developed during the dry season showed (1) proportionately greater development of vascular and fibrous tissue, together with smaller air passages; and (2) a considerable amount of stored starch, a food reserve quite lacking in portions developed during the humid season. It would seem, therefore, that in these two tropical amphibious forms the growth activity results during the dry season in the accumulation of reserve food; while during the wet season the growth is so vigorous that it uses not only the food then manufactured, but also that which has been accumulated during the previous months.—G. D. FULLER.

Osmosis in soils.—The recent results obtained by LYNDE,[16] showing that certain soils, notably the clays, promote the movement of soil water by acting as semipermeable membranes, increasing in efficiency with their depth, suggest

[15] CHOUX, P., De l'influence de l'humidité et de la sécheresse sur la structure anatomique de deux plantes tropicales. Rev. Gén. Botanique **25**:153–172. 1913.

[16] LYNDE, C. J., Osmosis in soils. Soils act as semipermeable membranes I. Jour. Phys. Chem. **16**:759–765. 1912; and LYNDE, C. J., and BATES, F. W., Osmosis in soils. Soils act as semipermeable membranes II. *Ibid.*, 766–781.

several applications of the theory of interest to ecologists and agriculturalists. These applications are of all the more interest because the efficiency of the finer soils has been shown[17] to be such that very considerable pressures may develop, which must be important factors in the upward movement of water in certain soils. It follows that whatever affects an increase in the concentration of the soil solution in the upper strata of such soils, whether it be the application of fertilizers or evaporation or the action of soil bacteria, aids materially in increasing the amount of water raised through the subsoil. Such factors may be involved in the increased water supply in climax mesophytic plant associations.—G. D. FULLER.

Liassic flora of Mexico.—WIELAND[18] has published a further study of the Liassic flora of Mixteca Alta, Mexico. The most significant botanical results were published in this journal.[19] The present contribution consists of a study of the composition of the flora largely for stratigraphical purposes. WIELAND shows that aggregates of species enable one to determine the age of a formation on the basis of the percentage of the major elements of the flora. He gives a table of the flora considered, with relationships to other floras that have been reported. The most conspicuous feature of this aggregate is the dominance of cycadophytes, which constitute 70 per cent of the flora. He gives illustrations of the overlapping of floras in the Jurassic. The suggestion of using the composition of a whole flora rather than certain species selected arbitrarily in the determination of strata seems to be a good one.—J. M. C.

The vegetation of Gothland.—THOMAS[20] has given an account of the vegetation of the Swedish island, Gothland. The island has an area of 1220 square miles, about half of which has more or less primitive vegetation. Some plants rare on the mainland, as the walnut and ivy, are common here. THOMAS, using the terminology of the English ecologists, finds that about half of the island was originally fenland (the term fen, by the way, should be adopted by American ecologists, as we have no good equivalent name for this very common formation); the vegetation aspect here and the constituent species are much as in the English fens. Calcareous bogs exist, comparable to those of Northern England. Various successions terminating in forest can be readily worked out, and the author appeals for an intensive study before virgin conditions are altogether gone.—H. C. COWLES.

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[17] LYNDE, C. J., and DUPRÉ, H. A., On osmosis in soils. Jour. Amer. Soc. Agron. 5:102–106. 1913.

[18] WIELAND, G. R., The Liassic flora of the Mixteca Alta of Mexico; its composition, age, and source. Am. Jour. Sci. **36**:251–281. *figs. 2.* 1913.

[19] BOT. GAZ. **48**:427–441. 1909.

[20] THOMAS, H. H., The vegetation of the island of Gothland. New Phytol. 10:260–270. *pls. 2.* 1911.

Anatomy and plant hybrids.—Miss HOLDEN[21] has suggested that anatomical structures may be used in the recognition of spontaneous hybrids which are identical in external appearance with ordinary species. There can be no question but that spontaneous hybrids are of extremely common occurrence, and when they are recognized at all, they are described as variations of recognized species. She uses as illustration a case of identical external structure covering profound differences in internal organization. A hybrid between *Betula pumila* and *B. lenta* was recognized by anatomical structure which otherwise appeared to be *B. pumila*. Another illustration is obtained from a form of *Equisetum* which was clearly proved to be a hybrid. If this weapon proves to be as efficient as Miss HOLDEN hopes, it will go far toward attacking successfully the problem of mutations.—J. M. C.

An Arkansas prairie.—As a result of a tour of a portion of Eastern Arkansas, HARPER[22] gives us some notes upon the phytogeography of the region, the most interesting of which concern an area of natural prairie, known as Grand Prairie, in Prairie County. The plant list, made about the middle of June, shows a very rich flora, estimated at 150 species, in which the Compositae, Leguminosae, and Juncaceae are well represented. No solution is offered of the problem of the occurrence of a prairie in this old flood plain other than indications that the soil moisture shows great extremes when spring and midsummer conditions are contrasted. The study of such areas in Arkansas seems to have been neglected and to offer excellent opportunities for botanical investigation.—G. D. FULLER.

The vegetation of the Hempstead Plains.—R. M. HARPER presents the interesting floral features of the Hempstead Plains, which are situated in the western part of Long Island, New York.[23] In this area there is a natural prairie of some 50 square miles in extent, much of which shows vegetation essentially undisturbed by human influences. The commonest herb is *Andropogon scoparius*, which also is common on many western prairies. HARPER discusses the possible causes of such a prairie, without coming to definite conclusions, except that climatic theories are ruled out, as is the influence of fire or of grazing. It is more likely, he thinks, that the Hempstead prairie is associated with some peculiar type of soil.—H. C. COWLES.

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[21] HOLDEN, RUTH, Anatomy as a means of diagnosis of spontaneous plant hybrids. Science N.S. **38**:932, 933. 1913.

[22] HARPER, R. M., Phytogeographical notes on the coastal plain of Arkansas. Plant World **17**:36–48. 1914.

[23] HARPER, R. M., The Hempstead Plains; a natural prairie on Long Island. Bull. Amer. Geog. Soc. **43**:351–360. *figs. 5.* 1911; also Torreya **12**:277–286. *figs. 7.* 1912.

Symbiosis between algae and sponges.—Two new species of red algae have been described by Madame WEBER VAN BOSSE[24] as belonging to the genus *Thamnoclonium* and living in symbiosis with a sponge which forms a continuous layer over the flattened and branching thallus of the plants. In the sponge are found imbedded small branches of the algae and also a series of filaments that are apparently epidermal outgrowths of the plant, but whose nature and origin could not be definitely determined on account of the scantiness of the material which was collected on some East Indian islands. The character of the relationship between the two symbionts remains to be determined.—G. D. FULLER.

Flora of New Guinea.—A volume of the botanical results of the Dutch scientific exploration of New Guinea during 1912 and 1913 has appeared.[25] Previous parts of the botanical report on New Guinea were reviewed in this journal.[26] The present part includes the Orchidaceae by J. J. SMITH. The species number 151, included in 41 genera, 5 of the species being described as new. By far the largest genus is *Dendrobium*, with 52 species, *Bulbophyllum* being next with 24 species. The present contribution brings together previous publications of SMITH, who is credited with 130 of the species and 3 of the genera. In *Dendrobium*, SMITH has described 47 of the 52 species.

Another volume of the botanical results of the Dutch scientific exploration of New Guinea during 1907 and 1909 has also appeared.[27] The preceding part was published in 1912.[28] In the present part the collaborators are HANS HALLIER and TH. VALETON. Altogether 9 families are presented, all monocotyledons, including 25 genera and 113 species, 62 of which are new. Most of the contribution consists of the presentation of Zingiberaceae by VALETON, including 10 genera and 92 species (56 new). The large genera are *Alpinia*, with 35 species (22 new), and *Riedelia*, with 28 species (21 new).—J. M. C.

A toxin from Rhizopus.—BLAKESLEE and GORTNER[29] have announced the discovery of a toxin produced by *Rhizopus nigricans*. The expressed juice from aerial filaments caused almost instant death when injected intravenously into rabbits. Since this fungus has a very wide distribution, and is almost

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[24] WEBER VAN BOSSE, Madame A., Sur deux nouveaux cas de symbiose entre algues et éponges. Ann. Jard. Bot. Buitenzorg. Suppl. **3**^{2}:587–594. 1910.

[25] Nova Guinea. Résultats de l'expédition scientifique Néerlandaise à la Nouvelle-Guinée en 1912 et 1913 sous les auspices de A. FRANSSEN HERDERSHEE. Vol. XII. Botanique. Livraison IV. 4to. pp. 1–108. *pls. 1–28*. Leide: E. J. Brill. 1913.

[26] BOT. GAZ. **49**:464. 1910; also **55**:462. 1913.

[27] Nova Guinea. Résultats de l'expédition scientifique Néerlandaise à la Nouvelle-Guinée en 1907 et 1909 sous les auspices de Dr. H. A. LORENTZ. Vol. VIII. Botanique. Livraison V. 4to. pp. 899–988. *pls. 160–179*. Leide: E. J. Brill. 1913.

[28] BOT. GAZ. **55**:462. 1913.

[29] BLAKESLEE, A. F., and GORTNER, ROSS AIKEN, On the occurrence of a toxin in juice expressed from the bread mould, *Rhizopus nigricans* (*Mucor stolonifer*). Biochem. Bull. **2**:542–544. 1913.

certain to infect starchy food under suitable moisture conditions, the suspicion is suggested that it may be related to certain destructive diseases of stock, such as pellagra ("corn-stalk disease"). Experiments are being conducted to discover the nature of the toxin and its possible relation to such diseases.—J. M. C.

A new form of Juglans.—BABCOCK[30] has investigated a new form of *Juglans californica* and described it as var. *quercina*, on account of the resemblance of its leaves to those of an oak. The new form has appeared on seven separate occasions among seedlings of at least three different trees of *J. californica*. Three working hypotheses were tested experimentally, the conclusions being that the form is not a hybrid of *J. californica* with *Quercus agrifolia* or some other oak; that it did not originate in certain teratological flowers that occur; and that in all probability it is a mutant.—J. M. C.

Vascular anatomy of Platycerium.—Miss ALLISON[31] has investigated the vascular anatomy of the rootstock of three species of *Platycerium*, uncovering a very unexpected complexity. The vascular cylinder is a complicated polystele, and in the largest form studied (*P. aethiopicum*) there are medullary strands also. She concludes that in the genus there is a progression from a comparatively simple type to a more complicated one. This anatomical structure certainly suggests a comparison with the Marattiaceae and the *Pteris*-like forms.—J. M. C.

Mosses of New Zealand.—DIXON[32] has begun a publication of a series of studies of the mosses of New Zealand, especially with reference to the herbarium of ROBERT BROWN at Christchurch. The first part contains a revision of the species of *Dicranoloma*, 16 species being recognized, 5 of which are described as new. These species have heretofore been included under *Dicranum*, and DIXON follows RENAULD'S treatment of this group as a separate genus.—J. M. C.

Medullosa pusilla.—In his *Studies in fossil botany* (1909), SCOTT referred to a very small *Medullosa* closely resembling the well known *M. anglica* except in size. He named it provisionally *M. pusilla*, and now has given a further account, with illustrations.[33] Further study shows that it differs in no important respect from *M. anglica*, and that its chief interest probably lies in the fact that it is the smallest *Medullosa* on record.—J. M. C.

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[30] BABCOCK, ERNEST B., Studies in *Juglans* I: Study of a new form of *Juglans californica* Watson. Univ. Calif. Publ. Agric. Sci. **2**:1–46. *pls. 1–12*. 1913.

[31] ALLISON, HARRIET E., On the vascular anatomy of the rhizome of *Platycerium*. New. Phytol. **12**:311–321. *figs. 5*. 1913.

[32] DIXON, H. N., Studies in the bryology of New Zealand, with special reference to the herbarium of Robert Brown. Part I. New Zealand Inst. Bull. no. 3. pp. 29. *pls. 1–4*. 1913.

[33] SCOTT, D. H., On *Medullosa pusilla*. Proc. Roy. Soc. London B **87**:221–228. *pl. 13. figs. 2*. 1914.

Embryo of Helminthostachys.—LANG[34] has supplied some much needed information in reference to the embryogeny of *Helminthostachys*. In a preliminary note[35] he had announced the existence of a well developed suspensor, but the present study furnishes many additional details. The embryo extends down into the prothallium before segmentation takes place, and the first two walls are transverse. The cell next to the neck of the archegonium, which may divide or not, forms the upper suspensor tier; the middle cell, which divides, forms the second suspensor tier; while the terminal cell forms the embryo proper. The hypobasal half of the embryo forms the foot, while from the epibasal half the stem tip, first leaf, and probably the first root arise. A comparative study of the embryogeny of Marattiaceae, Ophioglossaceae, and seed plants leads to the suggestion that "the suspensor represents the last trace of the filamentous juvenile state in development of the plant, and may have persisted in the seed-plants from their filicineous ancestry."—J. M. C.

Basidiomycetes of the Philippines.—GRAFF[36] has published a list of additions to the known Basidiomycetes of the Philippines with descriptions of new species. These additions number 33, about equally distributed between Hymenomycetes and Gasteromycetes. The new species are described in *Exidia*, *Laschia*, *Lentinus*, *Volvaria*, *Naucoria*, and *Bovista*.—J. M. C.

Nectaries and phylogeny.—After examining the nectaries of a large number of monocotyledons and dicotyledons, PORSCH[37] reaches the conclusion that the nectary is not only an organ of some phylogenetic significance, but that it furnishes additional proof of the derivation of the former from the latter.—C. J. CHAMBERLAIN.

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[34] LANG, WILLIAM H., Studies in the morphology and anatomy of the Ophioglossaceae. II. On the embryo of *Helminthostachys*. Ann. Botany **28**:19–37. *figs. 9. pl. 3.* 1914.

[35] Ann. Botany **24**:611. 1910.

[36] GRAFF, P. W., Additions to the basidiomycetous flora of the Philippines. Philippine Jour. Sci. **8**:299–307. *pls. 8–10.* 1913.

[37] PORSCH, OTTO, Die Abstammung der Monokotylen und die Blütennektarien. Ber. Deutsch. Bot. Gesells. **31**:580–590. 1914.